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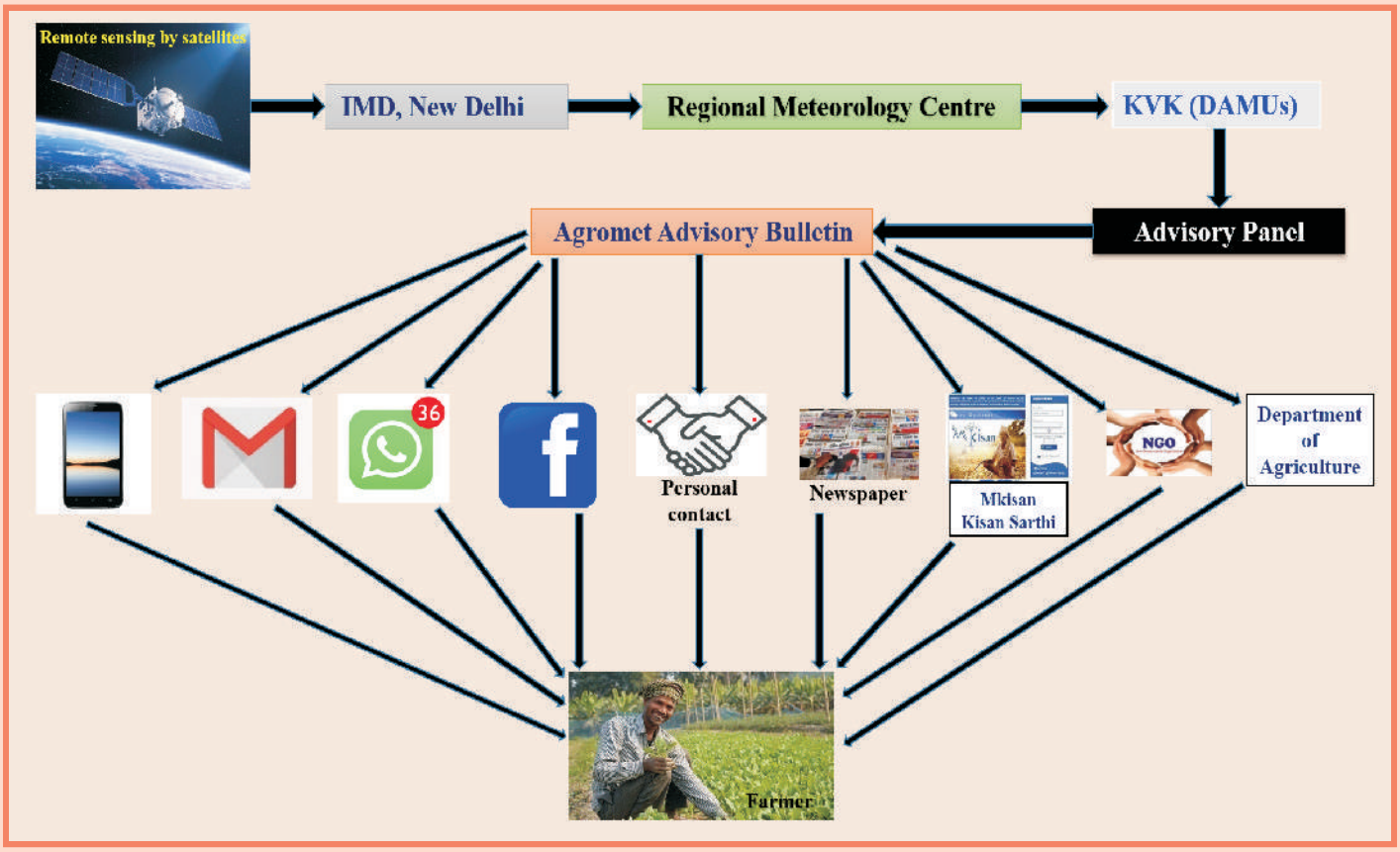
भाकृअनुप
ICAR

AGRO-ADVISORY SERVICES

Managing Risk and Production of Farmers



अटारी ATARI
JODHPUR
ZONE-II

ICAR-Agricultural Technology Application Research Institute, Zone-II

भाकृअनुप–कृषि प्रौद्योगिकी अनुप्रयोग अनुसंधान संस्थान, क्षेत्र–II

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Concept

Dr. U.S. Gautam, Deputy Director General (Agricultural Extension), ICAR, New Delhi

Dr. R.K. Singh, Assistant Director General (Agricultural Extension), ICAR, New Delhi

Authors

Dr. H.N. Meena, Principal Scientist (Agronomy), ICAR-ATARI, Jodhpur

Dr. J.P. Mishra, Director, ICAR-ATARI, Jodhpur

Bheem Sen, Senior Research Fellow, CRM Project

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Director

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डॉ. हिमांशु पाठक
सचिव (डेयर) एवं महानिदेशक (आईसीएआर)

Dr. Himanshu Pathak
Secretary (DARE) &
Director General (ICAR)

भारत सरकार
कृषि अनुसंधान और शिक्षा विभाग एवं
भारतीय कृषि अनुसंधान परिषद्
कृषि एवं किसान कल्याण मंत्रालय, कृषि भवन, नई दिल्ली 110 001

Government of India
Department of Agricultural Research and Education (DARE)
and Indian Council of Agricultural Research (ICAR)
Ministry of Agriculture and Farmers Welfare
Krishi Bhavan, New Delhi 110 001

FOREWORD

The Government of India established the National Medium Range Weather Forecasting Center (NMCWE) in 1988 with the mission to provide location-specific medium-range weather forecasts to farmers in the country. These forecasts serve as the foundation for agricultural weather advisory services, helping farmers making informed decisions to enhance productivity and mitigate risks. The Integrated Agricultural Meteorological Advisory Service (IAMA) was launched in April 2007 and further strengthened by India Meteorological Department in June 2008 by introducing district-level agricultural meteorological advisory services. This complemented the weather forecasts with localized agricultural advice.

Recognizing the critical importance of these services in rural areas, the initiative was named as the Rural Agricultural Weather Service during 12th Plan. Today, agricultural weather advisory information is disseminated to farmers at the block/tehsil level, accounting for the geographical and climatic diversity across districts, which significantly impacts crop types and production. In the face of changing climate patterns, characterized by unpredictable weather phenomena such as rainfall variability, temperature fluctuations, and storms, these advisories have become indispensable for farmers.

Another path breaking drive to enhance the precision and accessibility of the agro-advisories was undertaken through the collaborative action of India Meteorological Department and Indian Council of Agricultural Research (ICAR) in 2018 by establishing District Agro-Meteorological Units (DAMUs) at Krishi Vigyan Kendra (KVKs) in selected district. The purpose of the units was to provide real-time, accurate weather information tailored to the needs farmers of the locality thereby enabling them to make timely and effective decisions.

The DAMU led agro-advisory services (AAS) emerged as a vital tool for the farmers by enabling them to manage risks and optimize production amidst the challenges posed by climate change and weather adversaries. This technical bulletin aims to provide insights of the significant impact brought by AAS in reducing the risks, economizing upon costs and input usage and enhancing the profits to the farmers. I am confident that it will serve as an invaluable resource for all stakeholders of agriculture and agrometeorology.

I wish to compliment the authors of this technical bulletin 'Agro-advisory Services-Managing Risk and Production of Farmers' as well as the KVKs involved in the case study and the scientists of ICAR-Agricultural Application Research Institute, Zone II, Jodhpur (Rajasthan) for their dedicated efforts in bringing forth this publication.

Date: 5th September, 2024
Place: New Delhi

(Himanshu Pathak)

डॉ. ऊधम सिंह गौतम
उप महानिदेशक (कृषि विस्तार)
Dr. U.S. Gautam
Deputy Director General (Agril. Extn.)

भारतीय कृषि अनुसंधान परिषद्
कृषि अनुसंधान भवन–1, पूसा, नई दिल्ली 110 012
Indian Council of Agricultural Research
Krishi Anusandhan Bhawan-I, Pusa, New Delhi – 110012
Phone: 91-11-25843277 (O)
E-mail: ddg-extn.icar@gov.in ; us.gautam@icar.gov.in

MESSAGE

In order to provide location-specific medium-range weather forecasts to the farmers, the Government of India has set-up National Medium Range Weather Forecasting Center (NMCWE) in 1988. The medium range forecasts were the first step towards agricultural weather advisory services for taking informed decisions by the farmers and enhance their crop productivity while mitigating the risks. In the follow-up, in April 2007, Integrated Agricultural Meteorological Advisory Service (IAMA) was launched. The IAMA was further complimented with another initiative in June 2008 known as district-level agricultural meteorological advisory services.

During 12th plan, the IMD rechristened the IAMA as Rural Agricultural Weather Service (RAWS) to recognize the importance of agro-advisories for the farmers and the rural areas. The modern-day agricultural weather advisory information has even percolated to block and sub-division level for capturing the micro level variation in weather and rainfall etc which impacts crop yields and production significantly. The upsurge in weather extreme events under the realm of changing climate patterns, the agro-advisories are much more required for the benefit and welfare of the farmers.

Indian Council of Agricultural Research (ICAR) and India Meteorological Department (IMD) took a significant decision in 2018 to join hands for the collaborative programme for establishing District Agro-Meteorological Units (DAMUs) at Krishi Vigyan Kendra (KVKs) in selected district. The DAMU was aimed at enhancing the precision and accessibility of the agro-advisories by providing real-time, accurate weather information to the farmers and enable them to take decisions in time. The agro-advisory services (AAS) proved very effective to farmers. It helped them to optimize production and manage risks amidst the extreme weather events and climatic variations.

The technical bulletin 'Agro-advisory Services-Managing Risk and Production of Farmers' aims to provide insights of the significant impact brought by AAS in reducing the risks, economizing upon costs and input usage and enhancing the profits to the farmers. I am confident that it will serve as an invaluable resource for all stakeholders of agriculture and agrometeorology.

I wish to congratulate the authors and the scientist of ICAR-Agricultural Application Research Institute, Zone II, Jodhpur (Rajasthan) and the KVKs involved in the case study on DAMU for their painstaking efforts in bringing out a very useful and informative publication.

Date: 5th September, 2024
Place: New Delhi

(Udham Singh Gautam)

Dr. J.P. Mishra
Director

ICAR-Agricultural Technology Application Research Institute
Zone-II, Jodhpur-342 005, Rajasthan, India
Phone: +91-291-2748412, 2740516; Fax: +91-291-2744367
E-mail: atarijodhpur@gmail.com, zpd6jodhpur@gmail.com

PREFACE

The agriculture in India is the backbone of the rural space in India. The semi-arid and arid agro-climatic conditions prevailing over a large tract in the country where farming and farmers are dependent upon rains. These areas are diverse geographically and climatically. The S-W monsoon is central for the success of farming and an attractive return to farmers. The performance of S-W monsoon, at large, decides the nation's economy. A weak monsoon leading to farm distress slows down the growth in economy. The excessive and heavy rains cause natural calamities like floods, water stagnation, landslides and soil erosion which damages crops and assets of the farmers as well as non-farmers in rural areas. Although 100 per cent management of natural happenings and action are ruled out, the science led services of meteorology have helped precise prediction of weather patterns.

The farmers of the country have been looking for a precise service loaded with information and forecasts for their crops and other assets at the farm and the off-farm activities. To help farmers and other stakeholders Government of India established the National Medium Range Weather Forecasting Center (NMCWE) in 1988. The NMCWE aimed at providing location-specific medium-range weather forecasts to farmers in the country. Later in 2007, IMD initiated Integrated Agricultural Meteorological Advisory Service (IAMA) which was strengthened in 2008 by introducing district-level agricultural meteorological advisory services. This complemented the weather forecasts with localized agricultural advice. The Rural Agricultural Weather Service was the transformation of IAMA in 12th Plan.

The ICAR-KVK system have been pioneering in dissemination of new agricultural technologies amongst the farming community. Realizing the strength of KVKs in delivery of the services in rural areas, the IMD and ICAR entered into a MoU in 2018 and established District Agr- Met Units in KVKs. These KVKs are monitored and coordinated by the ICAR-Agricultural Technology Application Research Institute, Zone II, Jodhpur (Rajasthan), ensuring that farmers have access to the latest innovations and support.

Agro-Advisory Services (AAS) are vital link between meteorological forecasts and actionable insights for farmers. By translating weather forecasts into practical advice, AAS enables farmers to make informed decisions, minimizing the risks associated with adverse weather conditions and maximizing

agricultural productivity. Today, agricultural weather advisory information is disseminated to farmers at the block/tehsil level which has captured micro-level variation and significantly reduced the losses to crops. In Rajasthan, Haryana and Delhi, District Agro-Meteorological Units (DAMUs) have been established at 24 KVKs. These units have been delivering precise and up-to-date weather information directly to farmers at the block level, empowering them with the knowledge needed to manage their crops efficiently and sustainably.

The publication "Agro-Advisory Services-Managing Risk and Production of Farmers" is a testament to the ongoing efforts to bridge the gap between meteorological science and farming. It also reflects the commitment of ICAR-Agricultural Technical Application Research Institute, Zone II, Jodhpur and the KVKs to support the farming community in navigating the challenges posed by weather variability.

I extend my congratulations to the scientists and staff of ICAR-ATARI, Zone II, Jodhpur, and the KVKs for their dedication in bringing out this publication. I am confident that this bulletin will serve as a meaningful resource for all stakeholders involved in agriculture.

(J.P. Mishra)

Date: 5th September, 2024
Place: Jodhpur

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Executive Summary

India is facing a challenge to augment food production for the food security to its growing population, which is projected at 1.55 billion by 2037. This demands a substantial increase in food grain production to 547 million tons, all within the constraints of diminishing natural resources and escalating environmental stresses. A significant portion of Indian agriculture is dependent on rains for their successful output. The climate change further complicates the situation by increasing the frequency of extreme weather events, which pose severe risks to crop yields and the livelihoods of farmers. Effective management of land and water resources, along with the judicious use of agricultural inputs, is critical to mitigate these risks. The indiscriminate use of fertilizers and pesticides, often exacerbated by a lack of precise weather information, poses a threat to biodiversity and ecosystems. Therefore, integrating weather information with agricultural practices is crucial to optimize input use and enhance sustainability.

The Scientific Agro Advisory Services (AAS) have emerged as the important tool in providing data-driven recommendations to farmers. These services use advanced scientific research and technology to guide decisions on crop selection, pest management, irrigation, and soil health, thereby promoting both productivity and environmental sustainability. AAS is particularly vital in addressing the impacts of climate change by providing early warnings for extreme weather events and suggesting Adoptive strategies such as resilient crop varieties and water-saving practices. By promoting sustainable practices like soil health management, crop rotation, and integrated pest management, AAS supports long-term agricultural sustainability and resilience. The mechanism of AAS involves a structured process of data collection, analysis, recommendations, dissemination, and feedback. Advanced analytical tools and expert interpretation convert this data into actionable insights that are tailored to local conditions. These insights are disseminated through various communication channels to ensure accessibility and relevance for farmers. Feedback loops are integral to AAS, allowing for continuous improvement based on outcomes and farmer experiences.

Despite the clear benefits, the widespread adoption of AAS, in India, faces several challenges. These are limited access to technology, inadequate infrastructure, and high implementation costs. In addition, for ensuring the reliability and accuracy of these services, strong financial and human resource support is required for ongoing research and validation under local conditions. Addressing these challenges through improved infrastructure, targeted investments, and continuous innovation is essential for expanding the reach and effectiveness of AAS. This integrated approach can significantly enhance agricultural productivity, reduce vulnerability to climate risks and promote sustainable development of agriculture.

AAS also promote efficient use of inputs like water, fertilizers, and pesticides. Precision agriculture techniques enable farmers to apply resources based on specific crop needs and environmental conditions, minimizing waste and reducing environmental impact. Furthermore, AAS help farmers manage inherent agricultural risks, such as weather variability, pest infestations, and market fluctuations. By providing early

warning systems and predictive analytics, these services enable farmers to anticipate potential threats and implement precautionary measures. Additionally, AAS play a vital role in promoting sustainable agriculture by advocating practices that conserve resources and protect the environment.

The success of AAS in India is evident in the impact of District Agro-Meteorological Units (DAMUs) established in Krishi Vigyan Kendras (KVKs) under the collaboration of Indian Council of Agricultural Research (ICAR) and India Meteorological Department (IMD). The DAMU aims to provide localized and accurate weather-related advisories to farmers, improving their decision-making and agricultural practices. The DAMUs have disseminated over 104 agro-advisories to benefitting more than 10 lakh farmers annually.

The case study conducted during 2023-24 in Rajasthan and Haryana examine the impact of adopting AAS among farmers revealed 20.6% increase in crop yields and 31.6% increase in net returns of those farmers who adopted the agro-advisories provided under AAS compared to non-adopters. The study highlighted variable response to agro-advisories in various crops. While in rice, adopters recorded 24.8% and 29.9% increase in yield and net return, respectively, increase in pearl millet was 19.2 and 27.5%. Similar benefits were observed in other kharif and rabi crops demonstrating the widespread impact of AAS across diverse cropping systems.

The adoption of AAS not only enhanced productivity and profitability but also contributed to risk minimization. The substantial economic benefits and risk aversion due to ago-advisories make a a strong case for expanding and strengthening of DAMUs and AAS to other regions for improving agricultural output and facilitating farmers' welfare.

1. Background

India's population is projected to touch 1.55 billion in 2037 and shall reach to about 20% of the World's population by 2050. To provide two square meals to this population, about 547 million tons of foodgrains would be required. This enhanced food grains and other agriculture commodities are to be produced as a diminishing natural resource and escalating biotic and abiotic stresses. The uncertainties and extreme events of weather are on the rise under the realm of changing climatic pattern and behaviour. In India where about half of the cultivation is still rain dependent such uncertainties of weather and climate escalates the risk and minimise the chances of augmenting production. Under such circumstances, a comprehensive planning is crucial to mitigate economic and ecological impacts from extreme events, requiring the adoption of technologies for better land and water management to enhance their use efficiency. Another aspect is to economise the use of applied inputs like fertilizers and plant protection chemicals. The farmers, in absence of precise information about weather, often resort to prophylactic use of pesticides and fertilizers. The indiscriminate use of pesticides and fertilizers need to be curved to conserve biodiversity and natural ecosystems for which the weather information is to be integrated with application schedule of plant protection chemicals and other agro-chemicals

The Indian agriculture is typified with rainfed farming as more than 47% of the cropped areas are dependent on rainfall for their success. In such geographies weather significantly influences agricultural production having impacts at all stages of crop growth. The intensity and distribution of rainfall, which varies widely, affects crop growth, quality and amount of economic produce. Real-time strategies informed by weather forecasts can mitigate crop losses, guiding decisions on crop selection, sowing, weeding, pesticide application, irrigation scheduling, and fertilizer use, thus improving economic benefits for farmers. The climate change induced weather aberrations have escalated the extreme events causing severe damage to crops and assets of the farmers.

Successful agricultural strategies involve knowledge sharing, critical thinking promotion, effective tool and technology utilization, and understanding user priorities. Collaboration among biodiversity, conservation, and ecosystem sectors with National Meteorological & Hydrological Services is vital for promoting environmentally friendly and sustainable development. India, with its rich biodiversity, has a history of severe weather variability, crop failures, and recurrent famines, necessitating increased awareness and natural resource management to address climate change challenges like droughts, floods, and land degradation.

An integrated approach is essential for advancing improved technologies and practices for sustainable management of crops, livestock, soil, land, and ecological resources. Concerns about global agroecosystem sustainability highlight the importance of judiciously utilizing natural resources,

emphasizing climate's role in efficient soil and genetic material utilization. The World Food Summit Plan of Action (WFSPA) emphasizes commitments to ensure sustainable agricultural production, with agro-meteorologists playing a crucial role.

Indian smallholder farmers, with limited resources, are particularly vulnerable to weather and climate fluctuations, exacerbating food deficits and famine risks. Climate services are critical for rain-fed agriculture and livestock rearing livelihoods, requiring National Meteorological Services (NMS) to disseminate tailored climate information to support development efforts effectively.

The evolving capacity to deliver timely and accurate weather forecasts offers opportunities to reduce vulnerability to weather uncertainties, optimizing farm input management and enabling precise impact assessments. In this literature, we will delve into the realm of scientific agro advisory services, exploring not only their functionalities but also their potential tangible impacts on agricultural practices and outcomes.

1.1 CLIMATIC AND WEATHER UNCERTAINTIES IN RAJASTHAN, HARYANA AND DELHI

Agriculture in Rajasthan, Haryana, and Delhi is significantly impacted by weather and climate uncertainties, which pose substantial challenges to farmers. These regions, located in northern India, experience a variety of climatic stresses that affect agricultural productivity and sustainability.

(a) Rainfall and Water Stress

One of the most pressing concerns in these states is the variability and unpredictability of rainfall. Rajasthan, being a semi-arid region, frequently faces erratic monsoon patterns, leading to either drought conditions or sudden, intense downpours that can result in flooding. Similarly, Haryana and Delhi, which fall within the semi-arid to sub-humid zones, also suffer from inconsistent rainfall. In recent years, the delay in monsoon onset, early withdrawal, and uneven distribution have exacerbated water stress, severely affecting crop growth stages that are critical for yield formation. This erratic rainfall pattern necessitates a reliance on irrigation, which puts additional pressure on already depleting groundwater resources.

(b) Temperature Stress

Temperature extremes are another significant climatic challenge in these regions. Rajasthan, with its hot desert climate, and Haryana and Delhi, with their extreme continental climate, frequently experience temperature stress. The rising trend in maximum temperatures, especially during critical crop-growing periods, has been detrimental. In particular, crops like wheat, which are sensitive to terminal heat stress during the grain-filling stage, suffer from reduced yields and grain quality. Additionally, the increasing frequency of heatwaves can cause heat stress, leading to crop wilting, flower drop, and reduced fruit set, further impacting agricultural productivity.

(c) Hails and Strong Winds

Hailstorms and strong winds pose a substantial threat to agriculture in these regions, particularly during the Rabi and Kharif seasons. Hailstorms, though sporadic, can cause significant damage to crops like

wheat, mustard, and fruits, bruising or destroying plants and fruits, thereby reducing marketable yields. Strong winds, often accompanying storms, can lead to lodging in tall crops such as maize and sugarcane, which not only hampers growth but also complicates harvesting operations.

1.2 BIOTIC STRESSES

Biotic stresses, including pest and disease outbreaks, are exacerbated by changing weather patterns. Unpredictable rainfall and temperature fluctuations create favourable conditions for pests like locusts, aphids, and whiteflies, and diseases such as rust in wheat and blight in pulses, to thrive. These biotic stresses are often compounded by climate change, which can alter the life cycles and proliferation rates of these pests and diseases, making them harder to predict and manage.

2. Scientific Agro Advisory Services (AAS)

The modern agricultural landscape is involving intensely precision and efficiency. Scientific agro-advisory services have emerged as indispensable aids for enhancing precision and efficiency as well as minimising risks of the farmers worldwide. These services, grounded in a blend of cutting-edge scientific research and technological innovation, offer tailored recommendations and guidance across various facets of farming, ranging from crop selection to pest management, soil health to irrigation strategies and harvest planning to threshing and storage. By harnessing the power of data-driven insights, they not only optimize yields but also foster sustainability and environmental stewardship, ushering in a new era of agricultural practices.

Furthermore, scientific agro-advisory services play a crucial role in confronting the challenges posed by climate change. With increasingly erratic weather patterns, farmers face heightened risks to their operations. Leveraging climate modelling and forecasting techniques, these services provide early warnings for extreme weather events, empowering farmers to implement proactive measures safeguarding their crops and livelihoods. Moreover, they offer tailored adaptation strategies, recommending resilient crop varieties, alternative cropping patterns, and water-saving practices to navigate changing climatic conditions effectively.

An additional significant advantage of scientific agro-advisory services lies in their advocacy for sustainable agricultural practices. By emphasizing soil health management, crop rotation, and integrated pest management, these services encourage farmers to adopt approaches that enhance long-term productivity while minimizing environmental harm. Through personalized recommendations grounded in local conditions and scientific principles, farmers can optimize inputs, reduce chemical usage, and promote biodiversity, nurturing resilient and self-sustaining ecosystems.

However, despite their immense potential, the widespread adoption of scientific agro-advisory services faces several hurdles. Limited access to technology, inadequate infrastructure, and the high cost of implementation present significant challenges, particularly for farmers in developing regions. Furthermore, ensuring the reliability and accuracy of advisory systems requires ongoing validation and calibration against local conditions, highlighting the need for continuous research and development efforts to enhance their effectiveness and accessibility.

2.1 MECHANISM OF SCIENTIFIC AGRO ADVISORY SERVICES

Agro advisory services operate through a structured mechanism encompassing several essential stages, which include data collection, analysis, interpretation, recommendation generation, dissemination, and feedback. This systematic approach integrates various scientific disciplines, advanced technologies, and expert knowledge to deliver customized guidance to farmers. Here's an overview of the process:

(a) Data Collection

Agro advisory services initiate with the gathering of diverse datasets pertinent to agriculture. These datasets encompass information on weather patterns, soil moisture levels, crop varieties, prevalence of pests and diseases, and agricultural practices. Data collection methods vary, ranging from ground-based measurements and surveys to remote sensing techniques utilizing satellites. Real-time data acquisition is facilitated through automated weather stations, soil moisture sensors, and crop health monitoring devices.

(b) Data Processing and Analysis

Subsequently, collected data undergoes thorough processing and analysis using advanced analytical tools and algorithms. Statistical techniques, machine learning algorithms, and modelling approaches are employed to identify patterns, correlations, and trends within the data. This analysis aids in comprehending the relationships between different variables and their impact on agricultural productivity.

(c) Interpretation and Recommendation Generation

The analysed data is then interpreted by agricultural experts possessing expertise in agronomy, soil science, crop protection, and agricultural meteorology. Drawing insights from the data analysis and interpretation, specific recommendations tailored to each region's unique characteristics—including soil type, climatic conditions, crop selection, and existing agronomic practices—are generated for farmers.

(d) Dissemination of Advisory Services

Recommendations from agro advisory services are disseminated to farmers through various communication channels, such as WhatsApp, Facebook, Twitter, newspapers, extension services, mobile applications, websites, SMS alerts, radio broadcasts, television, or community meetings. Efforts are made to ensure timely delivery of advisory services in formats that are easily understandable and actionable, often incorporating local languages and context-specific information to enhance accessibility and relevance.

(e) Feedback and Iterative Improvement

Agro advisory services typically incorporate mechanisms for collecting feedback from farmers to evaluate the effectiveness of the recommendations provided and identify areas for improvement. Continuous monitoring of agricultural outcomes, including yield levels, pest incidence, and resource use efficiency, allows for iterative refinement of advisory services. This ensures that recommendations remain up-to-date and relevant to evolving agricultural conditions.

Hence, the mechanism of agro advisory services entails a cyclical process of data collection, analysis, interpretation, recommendation generation, dissemination, and feedback, aimed at enhancing agricultural practices, improving farm productivity, and promoting sustainability and resilience in farming communities.

3. Benefits of Agro Advisory Services (AAS)

3.1 MAXIMIZING CROP YIELDS

Scientific agro-advisory services offer invaluable support in maximizing crop yields, marking a significant benefit to farmers. Evolving alongside technological advancements and agricultural practices, these services furnish farmers with tailored guidance on crucial aspects such as crop selection, optimal planting and irrigation schedules, and cultivation techniques. Drawing from a diverse array of data sources including weather patterns, soil analysis, and historical trends, farmers can make well-informed decisions to enhance productivity. The result is a considerable increase in yields per hectare, bolstering farm profitability and ensuring food security.

(a) Leveraging Data for Informed Decision-Making

At the core of agro-advisory services lies a wealth of data encompassing soil health, weather patterns, crop performance, and market trends. Employing sophisticated data analytics and remote sensing technologies, these services provide farmers with real-time access to actionable insights. For instance, soil nutrient analysis enables customized fertilizer applications, ensuring optimal nutrient levels tailored to different crops and soil types. Likewise, weather forecasting tools empower farmers to make informed choices regarding planting schedules, irrigation management, and pest control measures, thereby mitigating risks and maximizing productivity.

(b) Precision Agriculture: Tailored Solutions for Enhanced Efficiency

Agro-advisory services embrace precision agriculture principles, tailoring interventions to meet the specific needs of individual blocks or crops. Utilizing satellite imagery and on-ground sensors, these services enable farmers to monitor crop health, identify anomalies, and pinpoint areas requiring attention. Armed with this information, farmers can implement targeted strategies such as variable rate application of inputs, precision irrigation systems, and localized pest management, minimizing resource wastage and optimizing efficiency. The adoption of precision agriculture facilitated by agro-advisory services ultimately leads to higher crop yields through enhanced productivity.

(c) Mitigating Risks with Early Warning Systems

Agriculture is susceptible to various risks, including adverse weather events, pest infestations, and diseases. Agro-advisory services mitigate these risks by providing early warning systems and predictive analytics. Leveraging historical data analysis and machine learning algorithms, these services forecast potential threats and alert farmers in advance, enabling proactive measures. For instance, forecasts of pest outbreaks prompt the deployment of integrated pest management strategies, reducing crop losses and increasing yields. Similarly, drought predictions facilitate the implementation of water conservation measures and adjustments in crop selection, ensuring resilience in the face of climatic uncertainties.

(d) Empowering Farmers through Knowledge Exchange

Beyond data and technology, agro-advisory services empower farmers through knowledge dissemination and capacity-building initiatives. Farmer awareness programs, mobile applications like Meghdoot & Damini, workshops, and farmer-scientist interface meetings serve as platforms for sharing best practices, agronomic recommendations, and innovative techniques. Farmers gain access to scientists and extension workers who provide personalized guidance and support, addressing specific challenges and optimizing production processes. By fostering a culture of continuous learning and knowledge exchange, agro-advisory services enable farmers to embrace progressive farming methods, enhance decision-making capabilities, and sustainably maximize crop yields.

3.2 OPTIMIZING RESOURCE UTILIZATION

In the current landscape of escalating pressures such as population growth, climate change, and resource scarcity, the judicious utilization of resources in agriculture has become imperative. Scientific agro-advisory services play a pivotal role in maximizing the efficiency of resources such as water, fertilizers, insecticides, and pesticides. Through the implementation of precision agriculture techniques, farmers can precisely allocate inputs based on crop requirements and environmental factors. This not only minimizes waste but also reduces the environmental footprint, fostering more sustainable farming methodologies.

(a) Precision Agriculture: Tailoring Inputs for Optimal Utilization

At the core of resource optimization lies precision agriculture – a departure from uniform to site-specific management of inputs. Agro-advisory services employ an array of tools, including satellite imagery, soil sensors, and GPS technology, to assess field variability and customize interventions accordingly. By dynamically mapping soil fertility, moisture levels, and crop health, these services enable farmers to apply inputs like fertilizers, insecticides, pesticides, and water precisely where they are most needed. This precision not only reduces waste but also enhances effectiveness, resulting in improved crop yields and minimized environmental impact.

(b) Data-Driven Decision Making: Leveraging Insights for Efficiency

Agro-advisory services harness the power of data analytics and predictive modeling to inform decision-making and optimize resource allocation. By analyzing historical data, weather patterns, and crop performance indicators, these services provide farmers with actionable insights for crop planning, irrigation scheduling, and pest management. For instance, by utilizing weather forecasts and soil moisture data, farmers can adjust irrigation schedules to match crop water requirements, thus conserving water and lowering energy expenditures. Similarly, monitoring systems for pests and diseases enable timely interventions, reducing the need for excessive pesticide applications and preserving ecosystem health.

(c) Balancing Nutrient Inputs: Tailoring Fertilization Strategies

Effective soil fertility management is essential for maintaining agricultural productivity while minimizing environmental harm. Agro-advisory services assist farmers in optimizing nutrient inputs

through soil testing, nutrient mapping, and tailored fertilization recommendations. By conducting soil analyses and generating maps of nutrient deficiencies, these services guide farmers in applying fertilizers judiciously, aligning nutrient supply with crop demand. Furthermore, by promoting practices such as precision nutrient management and organic amendments, agro-advisory services aid farmers in improving soil health, reducing nutrient runoff, and mitigating pollution risks in water bodies.

(d) Water Management: Improving Efficiency and Conservation

Water scarcity poses a significant challenge to agriculture, particularly in arid and semi-arid regions. Agro-advisory services offer innovative solutions for efficient water management, empowering farmers to optimize irrigation practices and conserve water resources. Through tools such as soil moisture sensors, evapotranspiration models, and remote sensing technology, these services provide real-time data on soil moisture levels and crop water requirements. Equipped with this information, farmers can implement drip irrigation systems, deficit irrigation strategies, and water-saving techniques tailored to their specific circumstances, thereby maximizing water-use efficiency and ensuring sustainable water management.

(e) Promoting Sustainable Practices: Ensuring Long-Term Viability

Beyond immediate gains in productivity and profitability, agro-advisory services advocate for sustainable farming practices that foster the long-term viability of agriculture. By endorsing methods like conservation tillage, cover cropping, and integrated pest management, these services help farmers cultivate resilient agroecosystems that rely less on external inputs and adapt more readily to changing environmental conditions. Moreover, by facilitating farmer education and community engagement, agro-advisory services promote the widespread adoption of sustainable practices, creating a ripple effect that benefits both farmers and the environment.

3.3 RISK MITIGATION

Farming inherently faces diverse risks, including shifts in weather patterns, pest infestations, and market volatility. Scientific agro-advisory services play a crucial role in helping farmers mitigate these risks through early warning systems and proactive measures. By analyzing historical data and employing predictive models, these services enable farmers to anticipate challenges and implement precautionary strategies. For example, timely alerts about pest outbreaks can prompt farmers to take preventive actions, thus safeguarding crops and preserving yields.

(a) Early Warning Systems: Anticipating and Preventing Threats

Agro-advisory services harness advanced forecasting models and data analytics to provide farmers with early warning systems for potential risks. By scrutinizing historical weather data, trends in pest incidence, and market dynamics, these services identify emerging threats before they escalate into crises. Weather forecasting tools, for instance, allow farmers to anticipate extreme events like droughts or storms, empowering them to undertake pre-emptive measures such as adjusting planting schedules or implementing water conservation strategies. Similarly, monitoring systems for pests and diseases alert farmers to localized outbreaks, facilitating timely interventions such as the use of pest-resistant crop varieties or targeted pesticide applications.

(b) Tailored Risk Management Strategies

Recognizing the unique characteristics of each farm, agro-advisory services advocate for customized approaches to address the specific challenges faced by individual farmers. Through personalized consultations, risk assessments, and farm evaluations, these services assist farmers in devising tailored risk management plans aligned with their particular circumstances. For instance, in regions prone to climate variability, agro-advisory services may recommend diversified cropping systems, resilient crop varieties, or crop insurance options to spread risk and protect against yield losses among smallholder farmers. Similarly, for large-scale commercial operations, these services may focus on financial risk management, market diversification, or hedging strategies to mitigate price fluctuations and ensure sustained profitability.

(c) Promoting Resilient Farming Practices

Agro-advisory services champion resilient farming practices that enhance the ability of agricultural systems to withstand and recover from shocks and stresses. By endorsing agronomic techniques such as soil health management, conservation agriculture, and agroforestry, these services help farmers build resilience against climatic extremes, soil degradation, and pest outbreaks. For example, conservation tillage and cover cropping methods improve water retention and soil structure, reducing the risks of erosion and drought stress. Likewise, agroforestry systems enhance biodiversity and ecosystem services, offering natural defences against pest and disease pressures while diversifying income streams for farmers.

3.4 ENHANCING PROFITABILITY

Agriculture fundamentally operates as a business, where profitability stands as a cornerstone for the sustainability of farming endeavours. Agro-advisory services contribute significantly to enhancing farm profitability by minimizing losses, optimizing input costs, and maximizing returns. Through the adoption of data-driven strategies, farmers can identify profitable solutions, refine production methods, and seize market opportunities, ultimately leading to improved financial outcomes, enhanced livelihoods for farmers, and overall economic growth in rural areas.

(a) Optimizing Input Costs: Maximizing Efficiency and Returns

Agro-advisory services play a pivotal role in enhancing profitability by optimizing input costs. Employing precision agriculture techniques, these services assist farmers in tailoring inputs such as seeds, fertilizers, and pesticides to match specific crop requirements and field conditions. By avoiding over-application and minimizing wastage, farmers can reduce input costs while sustaining or even increasing yields. Furthermore, agro-advisory services provide recommendations on cost-effective inputs and alternative management practices, empowering farmers to maximize efficiency and profitability on a per-hectare basis.

(b) Market Intelligence: Seizing Opportunities and Mitigating Risks

Navigating fluctuating market conditions remains a persistent challenge for farmers aiming to boost profits. Agro-advisory services play a vital role by furnishing farmers with crucial market insights, enabling

them to stay abreast of price disparities, shifts in demand, and export projections. Through thorough analysis of market data and forecasting upcoming trends, these services equip farmers to make well-informed decisions regarding crop selection, timing of sales, and marketing strategies. Additionally, by diversifying their range of crops and integrating value-added products, farmers can mitigate the impact of market volatility and tap into niche markets, ultimately enhancing profitability and resilience against uncertain market conditions.

(c) Risk Management: Safeguarding Investments and Preserving Yields

Mitigating risks is imperative to safeguard farm investments and maintain consistent profitability. Agro-advisory services provide tailored risk management strategies tailored to individual farm circumstances, aiding farmers in identifying and addressing potential threats proactively. By employing early warning mechanisms, monitoring pests and diseases, and accessing weather forecasts, these services empower farmers to anticipate risks and implement preventive measures such as resilient crop varieties, crop insurance, or adjustments in irrigation scheduling. By safeguarding yields and reducing production losses, agro-advisory services play an essential role in enhancing profitability and sustainability.

(d) Technology Adoption: Improving Efficiency and Productivity

Harnessing technological advancements is crucial for enhancing profitability in agriculture, with agro-advisory services playing a pivotal role in facilitating the integration of technologies. These services introduce farmers to a range of advanced tools, from precision farming devices and drone-assisted crop surveillance to IoT sensors and automated irrigation systems, aimed at improving resource management, reducing labour costs, and boosting productivity. Through technical support, training, and access to digital platforms, agro-advisory services enable farmers to fully harness technological capabilities, ultimately enhancing farm efficiency and profitability in the long run.

(e) Knowledge Transfer and Capacity Building: Empowering Farmers for Success

Fundamentally, the effectiveness of agro-advisory services in enhancing profitability hinges on their ability to equip farmers with expertise, knowledge, and resources. Through various channels such as workshops, training sessions, and extension programs, these services impart optimal techniques, agricultural insights, and business acumen to farmers. By fostering a culture of continuous learning and information sharing, agro-advisory services enable farmers to make informed decisions, embrace innovative methodologies, and Adopt to evolving market conditions. This approach to enhancing skills not only strengthens individual farm profitability but also enhances the resilience and competitive edge of agricultural communities as a whole.

3.5 FACILITATING SUSTAINABLE PRACTICES

In an era marked by heightened environmental awareness, prioritizing sustainable agricultural methods is essential for long-term viability. Agro-advisory services play a pivotal role in promoting the adoption of sustainable farming practices by providing valuable insights into soil health, biodiversity conservation, and ecosystem resilience. Through the advocacy of techniques such as agro-ecology, organic farming, crop rotation, and integrated pest management, these services assist farmers in reducing their

reliance on chemical inputs and mitigating environmental degradation. Consequently, sustainable agriculture enhances resilience against climate change while safeguarding natural resources for future generations.

(a) Promoting Soil Health and Conservation

The foundation of sustainable agriculture rests upon soil health, with agro-advisory services acting as facilitators in promoting practices that sustain and improve soil fertility. By conducting soil testing, devising nutrient management plans, and encouraging conservation tillage methods, these services empower farmers to enhance soil health while simultaneously reducing erosion and nutrient runoff. For instance, by advocating crop rotation, cover cropping, and agroforestry, agro-advisory services reinforce soil structure, increase organic carbon content, and suppress weed growth, thereby reducing reliance on synthetic fertilizers and herbicides. Flourishing soils not only foster robust crop yields but also serve as carbon sinks, aiding in climate change mitigation and enhancing ecosystem resilience.

(b) Water Conservation and Efficient Irrigation

Water scarcity presents a significant challenge to agriculture, particularly in regions vulnerable to drought and water stress. Agro-advisory services offer solutions for effective water management, enabling farmers to conserve water resources while maximizing crop productivity. Through technologies such as drip irrigation, moisture sensors, and evapotranspiration models, these services optimize irrigation scheduling and minimize water wastage. By promoting practices such as water recycling, rainwater harvesting, and deficit irrigation, agro-advisory services help farmers Adopt to changing climate patterns and mitigate the impact of water scarcity on agricultural production.

(c) Reducing Chemical Inputs and Pesticide Use

Excessive reliance on chemical inputs in agriculture poses threats to human health, biodiversity, and ecosystem integrity. Agro-advisory services advocate for integrated pest management (IPM) strategies, emphasizing cultural techniques, biological controls, and natural remedies over pesticides. Through pest population monitoring, crop rotation, and the use of pheromone traps, these services assist farmers in managing pest pressures while reducing reliance on pesticides and minimizing pesticide residues in food. Additionally, agro-advisory services promote organic farming methods, such as composting, green manures, and bio-fertilizers, to enhance soil health and microbial diversity while minimizing the use of synthetic inputs.

(d) Biodiversity Conservation and Habitat Restoration

Agriculture encompasses vast land areas, making it pivotal in global efforts to conserve biodiversity. Agro-advisory services endorse techniques that foster biodiversity conservation and habitat restoration within agricultural landscapes. By promoting the establishment of buffer zones, hedgerows, and wildlife sanctuaries, these services create refuges for beneficial insects, birds, and pollinators, thereby enhancing ecosystem functions and natural pest management. Moreover, agro-advisory services advocate for agroforestry systems that integrate trees and shrubs into agricultural environments, offering multiple benefits such as carbon sequestration, soil stabilization, and enhanced biodiversity.

4. District Agro-Met Units (DAMUs)

District Agro-Met Units (DAMUs) were established in Krishi Vigyan Kendras (KVKs) through a MoU between Indian Council of Agricultural Research (ICAR) and India Meteorological Department (IMD). This arrangement revolutionised the Agro-met Advisory Service (AAS) network by enhancing its reach to the grassroots level. The Agricultural Technology Application Research Institutes (ATARI's) played a significant role in coordination and monitoring of implementation of DAMUs and their functioning for the core deliverables for which they were established. It added to the Gramin Krishi Mausam Seva (GKMS) which aimed at empowering farmers with accurate and localized weather-related advisories. The GKMS has been an integral component of umbrella scheme of "Atmospheric & Climate Research Modelling Observing System & Services (ACROSS)" launched by the Ministry of Earth Sciences. The IMD in partnership with ICAR has installed automated agrometeorological units at select KVKs with an aim to provide farmers the essential weather-related information crucial for their farming.

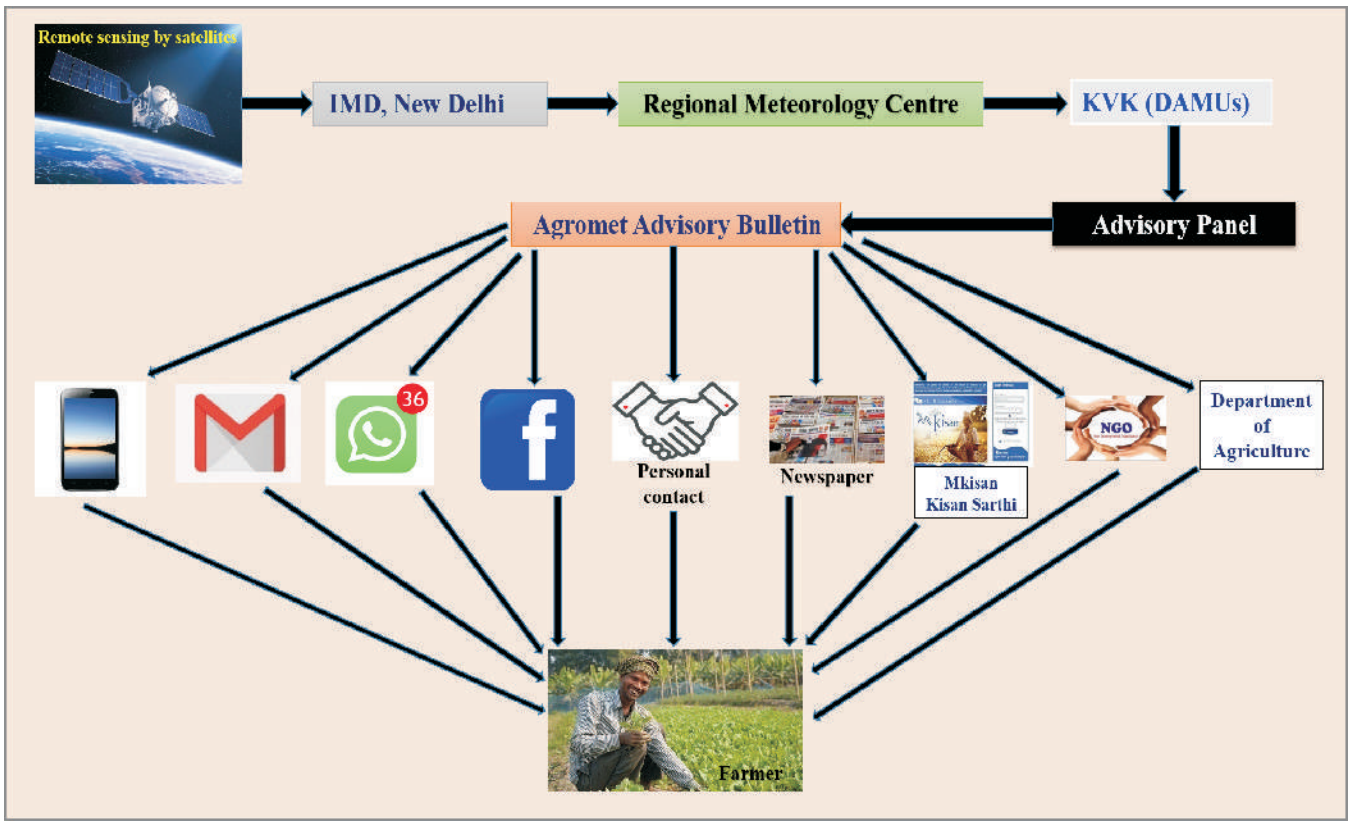

Fig. 1 DAMU and its Network

DAMU Units in Rajasthan, Haryana and Delhi

Rajasthan	Haryana	Delhi
Baran	Ambala	Delhi
Chittorgarh	Bhiwani	
Dholpur	Fatehabad	
Dungarpur	Gurugram	
Hanumangarh I (Sangaria)	Jhajjar	
Jaisalmer	Jind	
Jalore	Karnal	
Karauli	Kurukshetra	
Pali	Mahendragarh	
Sirohi	Panipat	
	Rohtak	
	Sonipat	
	Yamunanagar	

4.1 AGRO-ADVISORY SERVICES

The output of DAMUs has been very impressive. Approximately 104 agro-advisories were provided every year by each KVK in Zone-II (Rajasthan, Haryana and Delhi) benefiting over 10 lakh farmers, each year. Moreover, during 2018-2024, the KVKs where DAMUs were established also carried out more than 750 farmer awareness programs engaging 40,503 farmers. Besides, 162 farmer-scientist interactions were also organised involving around 5,500 farmers.

4.2 CASE STUDY: IMPACTS OF AAS AT FARM LEVEL

During 2023-24, a survey of farmers was undertaken by ICAR-ATARI, Jodhpur through KVKs of Rajasthan and Haryana. The analysis of the responses recorded through a structured questionnaire revealed substantial economic advantages of Agro Advisory Services (AAS) to those farmers who adopted those advisories (adopter) as compared to those who did not adopt these (non-adopter). The survey included 50 adopters and 50 non-adopters from the same area, each with similar cropping patterns. Total ~2100 respondents (adopters and non-adopters) were included in the case study. During the survey, both AAS-adopter and non-adopter farmers were asked about effect of adoption of agro-advisories for yield, cost of cultivation, saving in inputs and cost and net return along with risk minimization for all the major crops grown in these villages. In both crop seasons (Kharif & Rabi), the adoption of agro-advisories resulted into an advantage of 6.1 to 59% in yield to the adopting farmers with an average increase of 20.6%. The increase in net returns ranged from 12.5 to 64.2% over non-adopters, averaging at 31.6%. The benefit: cost ratio, a derivative of net return to cost of cultivation also showed identical trend.

4.2.1 YIELD AND NET RETURNS

(a) Kharif Crops

The predominant crops during kharif season in the studied villages were rice and pearl millet amongst cereals, greengram, blackgram and clusterbean amongst pulses, soybean, groundnut and sesame in oilseeds, and cotton in commercial crops. Total numbers of respondents in adopters and non-adopters categories were 614 and 561, respectively (Figure 2). The perceptions regarding the impact of AAS on production economics for various kharif crops are summarized below:

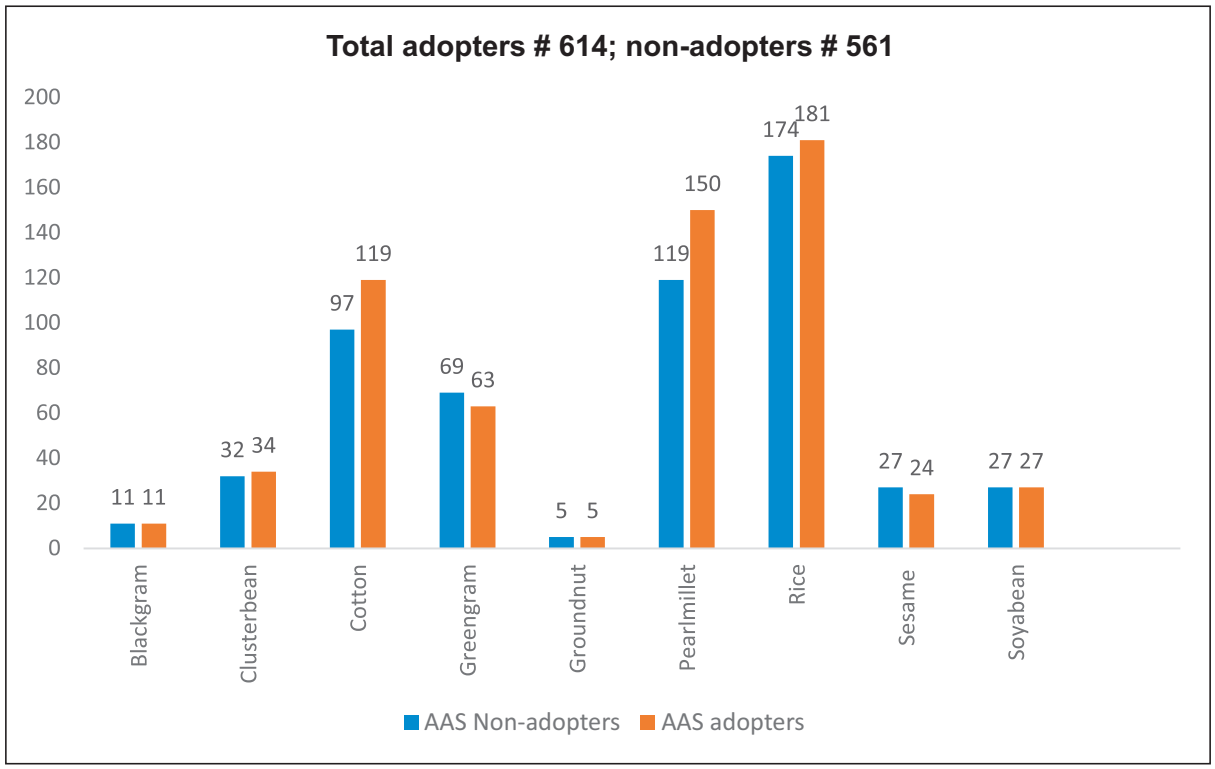

Fig.2: Distribution of Respondents amongst various kharif crops

Rice: Rice is predominant crop of kharif season in Haryana and also in some villages in high rainfall and assured irrigated blocks of Rajasthan**.** The average yield of adopter farmers was reported at 6741 kg/ha against 5403 kg/ha at non-adopters which translated into 24.8% higher yield with those farmers who adopted the agro-advisories and carried out the advised interventions or precaution as prescribed by the KVKs (Table 1). The net returns in rice for adopters was Rs. 1,54,122/ha which was 29.9% higher than the Rs. 1,18,651/ha received by non-adopters. Every rupee invested by adopters in rice cultivation gave a net benefit of Rs. 2.90 against Rs. 2.11 to non-adopters.

Pearlmillet: The pearl millet is the most preferred and suitable cereal crop in arid region of Rajasthan and Haryana. The crop has an inbuilt characteristic of drought escaping and withstands well in the water stressed conditions, a frequent and common feature of kharif season cropping in Rajasthan and some districts of

Haryana. The adopting farmers of agro-advisories achieved 2765 kg/ha of pearl millet grain yield with an advantage of 19.2% over non-adopters who harvested on an average yield of 2319 kg/ha of pearlmillet grains. The net returns for adopters were Rs. 52,887/ha, 27.5% higher than Rs. 41,466/ha for non-adopters (Table 1). The adopters received Rs. 0.63 more per rupee invested by them than the non-adopters which translated into an increase of 41.7% higher return per rupee invested in pearlmillet cultivation under the advisories of KVKs.

Greengram: Amongst various pulse crops, greengram is predominantly grown in Rajasthan and Haryana especially in low rainfall and moisture stressed areas. The crop is often exposed to water stress and farmers seek help of KVKs in managing the intermittent dry spells. The attack of pests and infestation of diseases such as YMV is also not uncommon. The farmers who adopted the agro-advisories and practices suggested in those agro-advisories by the experts at KVKs could harvest 1190 kg/ha seed yield of greengram registering an increase of 32.6% than those obtained by non-adopters (897 kg/ha) . The adopters received Rs 65840/ha net return which was 60.8% higher than net return of non-adopters of Rs. 40962/ha (Table 1). The adopters could be able to enhance yield and also save on the cost which augmented into net return over the increase in yield than the non-adopters. The adopter farmers could be able to enhance their income by Rs. 0.79 per rupee invested (B: C ratio 3.19) than the non-adopters (B:C ratio 2.4).

Blackgram: The farmers who adopted the advisories harvested seed yield of black gram at 1075 kg/ha against 972 kg/ha yield of non-adopters. The adopters seed yield of black gram was 10.6% higher than non-adopters. The average net return for adopters was Rs. 50744/ha which was 16.5% higher than those obtained by non-adopters (Rs. 43544/ha). Compared to non-adopters the adopters recorded much better per rupee invested with BC ratio of 2.11 (Table 1).

Clusterbean: Clusterbean is the important kharif pulses crops of hot arid ecology and concentrated largely in western Rajasthan. The crop can withstand against moisture stress. The adopter farmers of AAS achieved average seed yield of 1132 kg/ha of Clusterbean which was 14.2% higher than the seed yield obtained by non-adopters (991 kg/ha). The net returns of adopters of Rs. 38329/ha was 44% higher than Rs. 26623/ha of non-adopters. The BC ratio of adopters and non-adopter were 2.6 and 2.4, respectively (Table 1).

Soybean: Amongst the kharif oilseeds, soybean is an important crop for Rajasthan farmers and is distributed mostly in Mewar and Hadouti Region of the State. The adopter farmers of AAS on an average harvested seed yield of 1444 kg/ha of soybean registering a marginal increase of 6.1% over the seed yield of soybean of non-adopters (1361 kg/ha). The average net return of adopters was Rs. 34444/ha with 12.5% increase over that of non-adopters (Rs. 30,611/ha) (Table 1). Adopters and non-adopters received a return of Rs. 1.07 and Rs. 1.0 per rupee invested in soybean indicating thereby a marginal gain to adopted of AAS led advisories in soybean.

Groundnut: Groundnut is cultivated widely in Rajasthan both under hot arid rainfed ecologies and irrigated conditions of relatively better rainfall areas. The farmers have been cultivating this crop with multiple irrigation in light soils of western Rajasthan and Shekhawati region. The crop suffers from moisture stress

due to intermittent long dry spells and prone to collar rot disease and white grub insect-pest. The farmers adopting to practices and advisories of AAS of KVKs harvested seed yield of 2226 kg/ha of groundnut against 2016 kg/ha by non-adopters. The average net return for adopters was Rs. 115516/ha which was 38.5% higher than Rs. 83436/ha of net return received by non-adopters. The BC ratio of adopters was much better at 3.55 than those of non-adopters of 2.42 indicating thereby that adopters received Rs. 1.13 more at every rupee invested in Groundnut than non-adopters (Table 1).

Sesame: Sesame is short duration oilseed crop grown in several districts of Rajasthan and Haryana. The crop is very susceptible to higher moisture during maturity and water stagnation throughout and severely affected by phyllody disease. The adopter farmers achieved average seed yield of 758 kg/ha which was 30.7% higher than the 580 kg/ha yield of non-Adopters. The net returns of adopters was Rs. 79878/ha as compared to Rs. 48652/ha of non-adopters registering an increase of 64.2%. The BC ratio of adopters and non-adopters were 2.99 and 2.37, respectively (Table 1).

Cotton: Amongst the commercial crops, cotton is widely cultivated in Rajasthan and Haryana in select districts. The crop is predominantly irrigated in both the states and prone to insect pests like pink boll worm and several other sucking pests. The untimely rains during the picking seasons affect the productivity and quality of cotton. The adopter farmers harvested seed cotton yield of 2229 kg/ha which was 17.6% higher than that of non-adopters (1896 kg/ha). The net return of adopters was Rs. 120500/ha which was 23% higher than Rs. 98001/ha of non-adopters (Table 1). The higher BC ratio of 1.88 was recorded at adopters against 1.47 by non-adopters.

Table 1. Average yield of kharif crops, net returns and B:C ratio of AAS adopters and non-adopters

Crop	Yield (kg/ha)		% increase in adopters' yield over non adopters	Returns (Rs./ha		% increase in returns of adopters over non adopters	B:C Ratio	
	AAS Non adopters	AAS Adopters		AAS Non adopters	AAS Adopters		Non-adopters	Adopters
Rice	5403	6741	24.76	118651	154122	29.90	2.11	2.90
Pearlmillet	2319	2765	19.23	41466	52887	27.54	1.51	2.14
Greengram	897	1190	32.61	40962	65840	60.74	2.40	3.19
Blackgram	972	1075	10.66	43544	50744	16.53	1.81	2.11
Clusterbean	991	1132	14.21	26623	38329	43.97	2.40	2.60
Soyabean	1361	1444	6.12	30611	34444	12.52	1.00	1.07
Groundnut	2016	2226	10.40	83436	115516	38.45	2.42	3.55
Sesame	580	758	30.71	48652	79878	64.18	2.37	2.99
Cotton	1896	2229	17.61	98001	120500	22.96	1.47	1.88

(b) Rabi Crops

The predominant rabi season crops in the studied villages were barley and wheat (cereals), chickpea (pulses), mustard (oilseed) and Isabgol (medicinal). Total numbers of respondents in adopters and non-adopters categories were 475 and 467, respectively (Figure 3). The perceptions regarding the impact of AAS on production economics for various rabi crops are summarized below:

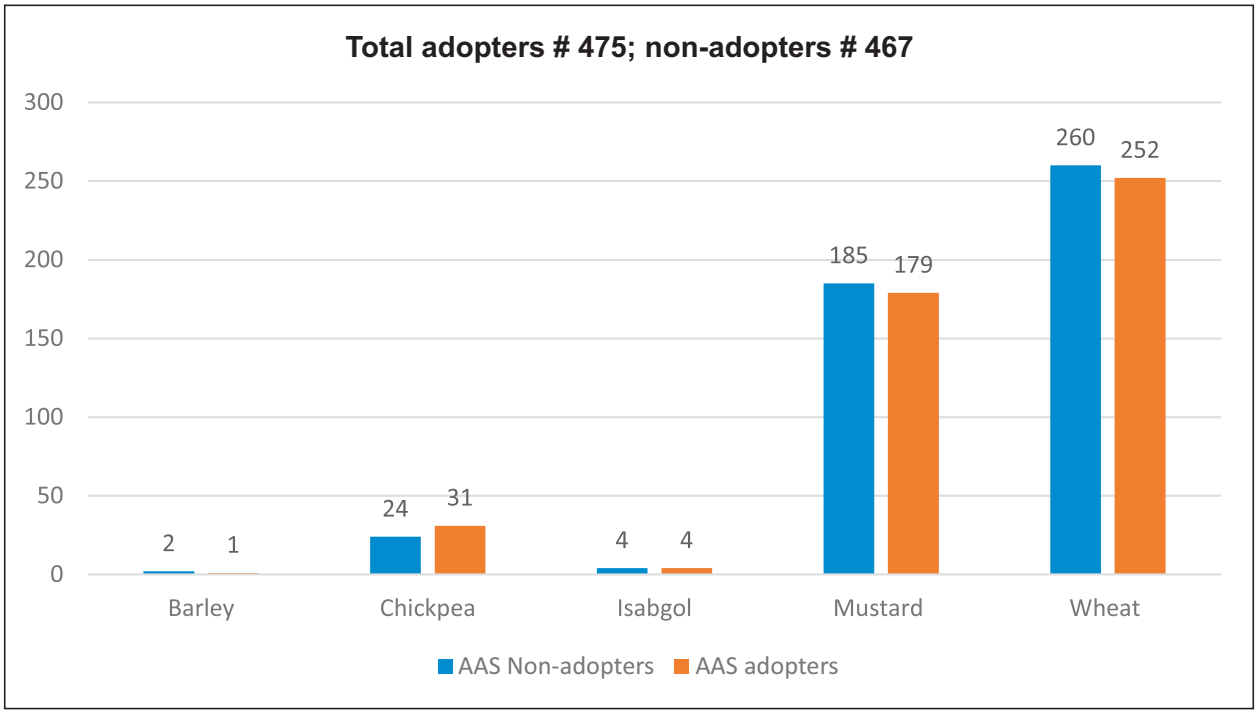

Fig.3: Distribution of Respondents amongst various Rabi crops

Barley: Barley thrives in cool, temperate climates with moderate rainfall and well-drained soils, demonstrated significantly higher yields under improved agricultural practices as directed by AAS bulletins. Adopter farmers achieved a yield of 4000 kg/ha, which is 59% higher than the yield of 2515 kg/ha observed among non-adopter farmers. Consequently, the net returns for adopters increased to Rs. 41,000/ha, representing a 23.9% increase compared to the Rs. 33,084/ha for non-adopters. The benefit-cost (BC) ratio of adopters was 2.78 aginst 2.26 of non-adopters. (Table 2).

Wheat: Wheat is best suited to regions with cool to moderately warm temperatures, well-drained fertile soils, and moderate rainfall. However, wheat production is often hindered by climatic obstacles such as terminal heat stress during the grain-filling stage, late frost, and unpredictable rainfall patterns, which can adversely affect grain quality and yield. Adopter farmers achieved a yield of 5380 kg/ha, which is 20.2% higher than the 4475 kg/ha yield of non-adopters. The net returns for adopters were Rs. 1,00,877/ha, representing a 28.1% increase over the Rs. 78,741/ha for non-adopters. This improvement in productivity and net return increase in benefit-cost (BC) ratio of adopters to 2.57 against 1.83 of non-adopters (Table 2).

Chickpea: Chickpea is ideally suited to semi-arid climates with cool to moderate temperatures and well-drained soils, requiring approximately 600 to 900 mm of rainfall annually, concentrated in the growing season. Major obstacles to its production include susceptibility to diseases such as *Ascochyta blight* and *Fusarium* wilt, as well as sensitivity to soil salinity and waterlogging. Adopter farmers achieved a yield of 1632 kg/ha, which represents a 27.9% increase over the 1276 kg/ha yield of non-adopters. The net returns for adopters were Rs. 61,957/ha, 54.8% higher than the Rs. 40,031/ha achieved by non-adopters. This resulted in a benefit-cost (BC) ratio of 2.67 of adopters as compared to 2.15 of non-adopters (Table 2).

Mustard: Mustard crop requires a cool and dry environment during the growing season, typically with temperatures ranging between 10°C to 25°C, and well-drained, loamy soils. Mustard cultivation faces several biotic stresses, including pests such as aphids and diseases like white rust, as well as abiotic stresses such as drought, frost, and salinity, which can significantly impact yield. Farmers who followed AAS and adopted improved cultivation practices achieved a yield of 2,247 kg/ha, 17.8% higher than the 1,907 kg/ha yield of non-adopters. This increase in yield translated to higher economic returns, with adopters earning Rs. 1,02,360/ha, 26.1% more than the Rs. 81,196/ha earned by non-adopters. The Benefit-Cost (BC) ratio was 2.47 for non-adopters to 3.49 for adopters (Table 2).

Isabgol: Isabgol is an important medicinal crop known for its high fiber content, thrives in semi-arid climates with moderate temperatures ranging from 15°C to 30°C and well-drained sandy loam soils. The crop plays a crucial role in pharmaceutical industries and traditional medicine. Its cultivation is often challenged by fungal diseases like downy mildew and insect pests, as well as by drought and salinity, which can hinder yield potential. Farmers who implemented the Agro-Advisory Services (AAS) achieved a yield of 858 kg/ha, which is 17.1% higher than the 733 kg/ha yield obtained by non-adopters. This increase in productivity led to net returns of Rs. 97,368/ha for adopters, reflecting a 24.6% improvement over the Rs. 78,123/ha earned by non-adopters. The benefit-cost (BC) ratio of adopters was much higher at 3.15 against 2.5 of non-adopters (Table 2).

Table 2. Average yield of Rabi crops, net returns and B:C ratio of AAS adopters and non-adopters

Crop	Yield (kg/ha)		% increase in yield over AAS non adopters	Returns (Rs./ha)		% increase in returns over AAS non adopters	B:C ratio	
	AAS Non adopters	AAS Adopters		AAS Non adopters	AAS Adopters		AAS Non adopters	AAS Adopters
Barley	2515	4000	59.05	33084	41000	23.93	2.26	2.78
Wheat	4475	5380	20.25	78741	100877	28.11	1.83	2.57
Chickpea	1276	1632	27.90	40031	61957	54.77	2.15	2.67
Mustard	1907	2247	17.80	81196	102360	26.06	2.47	3.49
Isabgol	733	858	17.10	78123	97368	24.64	2.50	3.15

4.2.2 INCOME DYNAMICS OF ADOPTERS AND NON-ADOPTERS

(a) Kharif Crops

The comparison between adopters and non-adopters of KVK advisories (Table 3) reveals significant income disparities across various Kharif crops. Non-adopters faced notable income losses, with the most significant losses in cotton (Rs.35,325/ha, 29.13%) and rice (Rs.38,514/ha, 22.38%). On the other hand, adopters enjoyed substantial income gains, with cotton and rice again leading at Rs.35,030/ha (28.44%) and Rs.26,443/ha (20.78%), respectively. Other crops like sesame, cluster bean, and greengram also showed considerable income gains for adopters, with sesame witnessing a 37.16% increase (Rs.16,736/ha) and cluster bean and greengram seeing gains of 31.45% and 30.15%, respectively. Black gram and soyabean had the smallest income differentials, both for non-adopters and adopters, at Rs.7,200/ha and Rs.3,833/ha, respectively (Table 3). Overall, adopting KVK advisories clearly led to significant income gains and mitigates losses across diverse cropping systems.

Table 3. Loss in income to non-adopters of AAS as compared to adopters in different Kharif crops

Crops	Loss of income to non-adopters as compared to adopters		Gain in income to adopters as compared to non-adopters	
	(Rs/ha)	%	(Rs/ha)	%
Rice	38514	22.38	26443	20.78
Pearlmillet	16894	26.86	13648	22.25
Blackgram	7200	16.61	7200	16.61
Greengram	17351	32.87	18739	30.15
Clusterbean	10356	38.83	9615	31.45
Ground nut	14602	17.48	14602	12.62
Soyabean	3833	12.60	3833	12.60
Sesame	24361	31.79	16736	37.16
Cotton	35325	29.13	35030	28.44

(b) Rabi Crops

Table 4 illustrates the income differences between adopters and non-adopters of KVK advisories for various rabi crops, showcasing the financial advantages of adoption. For non-adopters, the most significant income losses occurred in mustard (Rs. 26,163/ha, 22.32%) and isabgol (Rs. 25,923/ha, 33.18%). On the other hand, adopters experienced notable income gains, particularly in mustard, with an increase of Rs. 24,759/ha (27.54%), and chickpea, which saw a rise of Rs. 12,462/ha (25.22%). Wheat and barley also demonstrated clear benefits for adopters, although the percentage gains were somewhat lower. Hence, adopting KVK advisories led to meaningful income improvements and helped reduce the financial risks for farmers across these crops.

Table 4. Loss in income to non-adopters of AAS as compared to adopters in different rabi crops

Crops	Income loss as compare to adopter farmers	% Income loss as compare to adopter farmers	Additional income to adopter farmers	% gain in income over Non adopter farmers
Barley	10722	23.76	5200	14.52
Wheat	24061	28.32	21625	16.05
Chickpea	21301	25.03	12462	25.22
Mustard	26163	22.32	24759	27.54
Isabgol	25923	33.18	18006	18.50

4.2.3 COST SAVING AND RISK AVERSION

(a) Kharif Crops

The KVK advisory services have significantly contributed to input cost savings across various Kharif crops (Table 5), with substantial risk aversion percentages. The highest input cost savings were observed in cotton (Rs.10,759) with a 37.87% risk aversion, followed by greengram (Rs.8,275) at 32.42%, and pearl millet (Rs.6,866) at 29.71%. Sesame, clusterbean, and groundnut also benefited from considerable savings of Rs.5,234, Rs.4,144, and Rs.4,740, respectively, with risk aversion percentages ranging between 26.36% and 30.51%. While soyabean and blackgram showed lower savings of Rs.1,805 and Rs.1,655, their risk aversion percentages were 12.60% and 16.61%, respectively. Overall, these results highlight the positive impact of KVK advisories in reducing input costs and mitigating risks across diverse kharif cropping systems.

Table 5. Saving in inputs and risk aversion to adopters in different kharif crops

Crops	Saving of input-cost due to KVK advisory	Risk aversion (%)
Rice	7093	26.14
Pearlmillet	6866	29.71
Blackgram	1655	16.61
Greengram	8275	32.42
Clusterbean	4144	30.51
Groundnut	4740	26.36
Soyabean	1805	12.60
Sesame	5234	30.08
Cotton	10759	37.87

(b) Rabi Crops

The implementation of KVK advisories has led to input cost savings significantly across various crops, coupled with a notable reduction in associated risks (Table 6). Barley saw a reduction in input costs by Rs.5400, with a risk aversion of 5.2%. Chickpea and Isabgol benefited from similar advisories, resulting in input cost savings of Rs.4227 and Rs.4350, respectively, with risk aversion percentages of 27.30% and 29.45%. Mustard recorded the highest input cost savings at Rs.8454, alongside a risk aversion of 28.79%. Wheat, another major crop, experienced a substantial input cost saving of Rs.9909, with a corresponding risk aversion of 27.93%. These figures underscore the crucial role of KVK advisories in enhancing economic efficiency and mitigating risk in crop production.

Table 6. Saving in inputs and risk aversion to adopters in different rabi crops

Crops	Saving of input cost due to KVK advisory	Risk aversion (%)
Barley	5400	5.2
Wheat	9909	27.93
Chickpea	4227	27.30
Mustard	8454	28.79
Isabgol	4350	29.45

5. Way Forward

The establishment of DAMUs in Krishi Vigyan Kendras (KVKs) has facilitated the dissemination of critical weather-based advisories to farmers, leading to notable improvements in crop yields, net returns, and overall farm economics. The findings of case study underscore the substantial impact of District Agro-Meteorological Units (DAMUs) and Agro-Advisory Services (AAS) on enhancing agricultural productivity and profitability in different regions of Rajasthan, Haryana. The farmers who adopted the agro-advisories received significant economic advantages compared to those who did not adopt, across various crops.

The agro-advisories adopting farmers received highest gain of 60.7 per cent in income in greengram to the lowest of 12.5 per cent in soybean than non-adopters. This translates into a benefit of 5.18 USD per day assuming duration of green gram of 60 days from seed to seed and 0.53 USD/day in soybean at 90 days duration at a conversion rate of Rs. 80 per USD. This benefit happened because adopting agro-advisories enhanced productivity and complimented to the return of the farmers by minimising risk and savings on the costs of the inputs due to appropriate adjustment by the farmers in rescheduling of their application. The economic benefits indicate that the adoption of AAS can significantly enhance the livelihoods of farmers. The structured and scientifically formulated advisories provided by DAMUs and KVKs have proven to be effective in guiding farmers towards more efficient and sustainable agricultural practices.

More comprehensive mechanisms of interpretation of weather data and their application in formulating the scientific agro-advisories are needed with complete backup of technical institutions and experts available in the SAUs/ICAR institutions in a given district/region. The expertise available in KVKs, sometimes, is not adequate to provide the advisories for complex problems, hence a 'Scientific Advisory Committee' needs to be put in place at SAU level to formulate Scientific Agro-advisories (SAAs) which can be disseminated by KVKs in convergence of district agriculture department.

The entire landscape of agricultural practices, input application and their management are changing very fast to adjust them against the changing climatic behaviour. Indian agriculture is still predominantly rainfed. In some of the commodities like pearlmillet, kharif pulses and oilseeds, cotton and several other location specific crops like clusterbean and mothbean, the rain decides the fate of their success on over 80-85% of area. The changes at micro level in weather pattern with rising frequency of extreme events necessitates a strong mechanism for seamless and in-time flow of agro-advisories to farmers. The evidences generated in the case study involving 2117 farmers of several districts and blocks of Rajasthan and Haryana have proven the usefulness of agro-advisories in resolving farmers' stress. What is more required is that the

weather-based advisories are integrated into agricultural planning and decision-making not only at micro-level but also at macro-level. This will bring resilience against weather aberrations at micro level by boosting the individual farm productivity and profitability. At macro-level such systemic investment will contribute to sustainable agricultural development in the region. The per day return of 5.18 USD to a farmer is capable to drive him out from extreme poverty to next level of income group and earn a respectable living in society. This is the societal benefit face of AAS which needs to be underscored prominently and seriously.

The Government need to take a policy decision to institutionalise the AAS through DAMU or some modified version of DAMU for continued benefit of agro-advisories reaching to millions of farmers. The two way interactive platform of Kisan-Sarathi could be utilised to enhance the reach of the AAS. A public-private model could also be thought of to roll out the paid agro-advisories in relatively high productivity regions and high value commodities where the benefits of AAS can lead substantial gains. However, this will require more evidence to be generated for the economic advantages of the AAS in high value commodities cultivated in farmers' fields in open and those grown in protected conditions. The other approach could be generating the evidence of AAS benefits to households in entirety including crops, livestock, on-farm enterprises and off-farm activities as well as saving to farm assets. To begin with the most vulnerable districts/blocks could be chosen for such institutional establishment.

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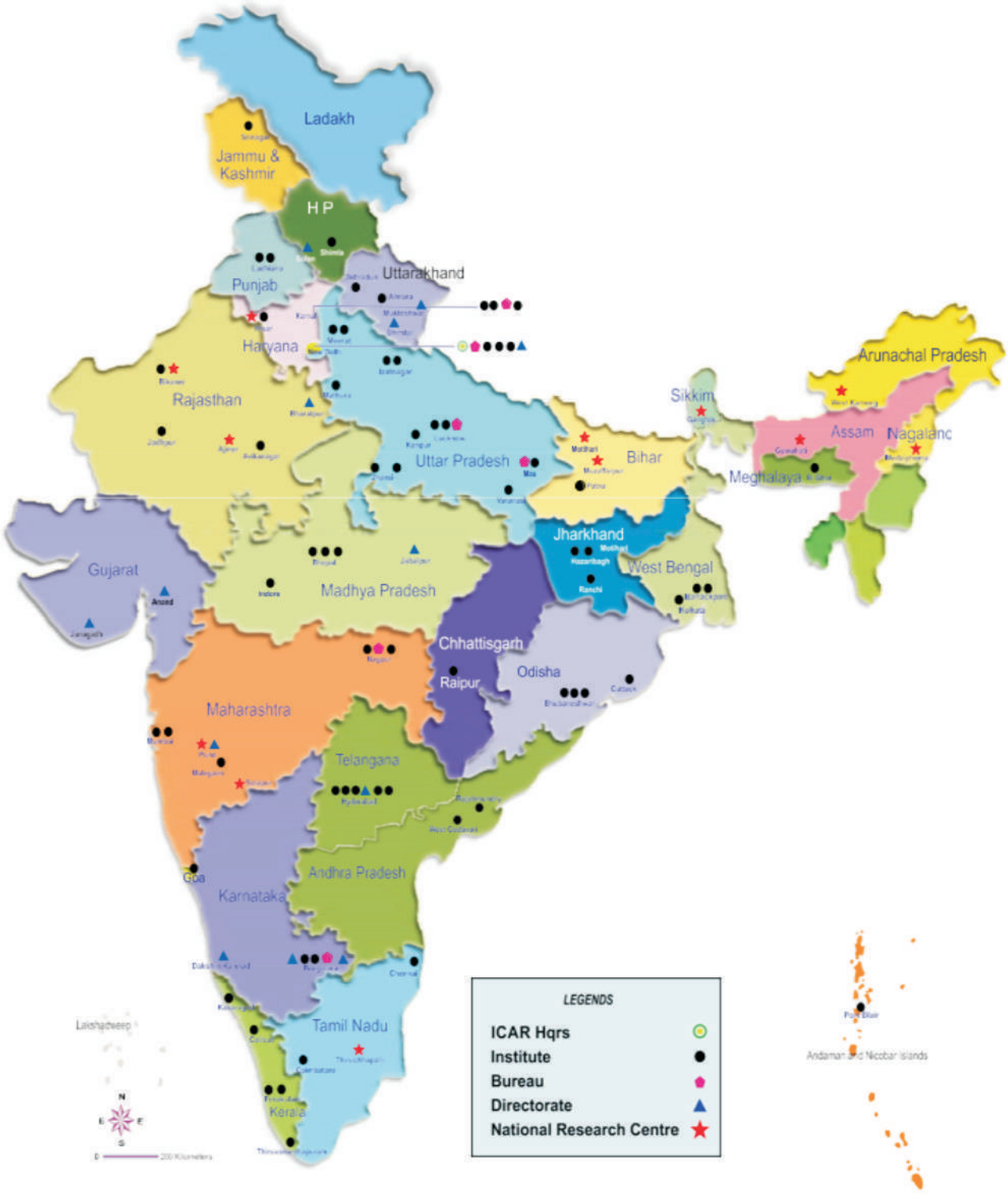

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ICAR-Agricultural Technology Application Research Institute, Zone-II

Jodhpur - 342 005 Rajasthan, India
Tel. : +91-291-2740516, Fax : 0291-2744367
E-mail : atari.jodhpur@icar.gov.in
Website : www.atarijodhpur.res.in

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