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Piloting Pulse Producer Support System Through ICT Enabled Services for Enhanced Climate Resilience

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ABSTRACT

Background: In peninsular India, the frequency of climate-related risks is significantly lowering agricultural productivity and farmers' standard of living. Reducing losses in the agriculture sector requires precise and timely weather information, weather based advisories on crop production, protection and post-harvest. Disseminating agromet advisories directly to the farmers using ICT tools allows farmers to adopt appropriate corrective measures, minimize loss and ensure climate resilient agriculture. In this sense, the Tamil Nadu Agricultural University established an Automated Agromet Advisory Web cum Mobile App (TNAU-AAS) in 2018, which sends location, crop and stage specific agromet advisories directly to farmers' mobile App.

Methods: TNAU-AAS App was evaluated in pulse crops as "Piloting pulse produce support system through ICT enabled services" between 2019 and 2021 in three TNAU centers under three different eco systems namely irrigated (Coimbatore), rice fallow (Aduthurai) and rainfed (Kovilpatti). Pulse growing farmers were registered in this smartphone application for agromet advisory based response farming.

Result: The TNAU-AAS App had delivered approximately 10-12 advisories to each farmer, tailored to their unique crop and stage during the cropping period. Survey results inferred that the farmers received timely notifications on their mobile phones, 2-3 days in advance, which assisted them in preplanning. Occurrences of pests and diseases were well aligned (68-83%) with TNAU- AAS recommendations and the climate vulnerability of non AAS farmers is more than AAS farmer. According to partial budget analysis, the irrigated, rice fallow and rainfed black gram farmers have gained Rs. 2800, Rs. 2300 and Rs. 1900 per ha, respectively. It is concluded that the ICT-enabled agromet advisory system guarantees timely alerts, boosts labor and land productivity, lowers input loss and shields crops from weather-induced pests and diseases as well as climatic variability risk.

Key words: Automation in Advisory, Climate Resilience, Climate variability, Pulses.

INTRODUCTION

The peninsular India's proximity to the equator offers more solar radiation and a peculiar monsoonal climate, which provides more opportunities to cultivate a range of crops and promote food security. Agriculture is largely dependent on the weather for its success and there is a strong association between weather patterns during the cropping season (Srinivasa Rao *et al.,* 2016). Tamil Nadu has around seven million hectares of cultivable land, of which approximately 45 per cent (3 Mha) is under rainfed agriculture, where farming is a gamble with the weather.

Indian states depend on monsoon rains to replenish their water resources, hence monsoon failures cause severe drought and water scarcity. Worldwide, everyone is evidencing the impact of climate change, particularly increased frequency of drought and flood. In a similar fashion, climate variability impedes the profitability of agriculture, especially for rainfed farmers who lack sufficient resources. Several studies on climate change concluded that there is a spatial and temporal shift in rainfall season, quantity and distribution, resulting in a spatial shift in crop potential and a change in length of growing season. Crop production is subjected to considerable instability from year to year due to its dependence on rainfall, which is slightly erratic and variant in space and time. These risk prone areas exhibit a wide variation and instability in yields (Mhizha, 2010).

In recent times, it has become apparent that adverse climatic conditions have significantly hindered the productivity of various cropping systems, despite the considerable progress made in technology. The strongest evidence stems from the agricultural prosperity of 2011-2012, when an ample

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supply of precipitation enabled Tamil Nadu to produce abundant harvests, contrasted with the catastrophic loss of half of the cultivated land in 2016-17 as a result of insufficient precipitation, whereas the agricultural activity in the intervening years was erratic.

Pulses, one of the most important food crops farmed worldwide, have a high protein content and hence play an essential role in the diet of the great majority of India's low-income and vegetarian people (Singh Mohan Jitender, 2022). Over the years, pulse crops such as black gram and green gram have occupied a larger area in Tamil Nadu, but their productivity has declined as a result of rainfed cultivation and vagarious nature of monsoon, often causes complete crop losses. The yield gap for pulse crops ranged from 56 to 67%, indicating that there is a great deal of room for improvement by implementing weather-based crop management. Climate anomalies are the main cause of the erratic supply and price of pulses. One of the elements that controls the abundance of insect pests in the pulse ecosystem is weather (Singh *et al.,* 2019).

Numerous studies documented that, in India, insect pests accounted for 7 to 35% of the total losses of pulses. In contrast, the combined infestation of pests and diseases resulted in an estimated yearly output loss of over 30% under dry land conditions (Sharma *et al.,* 2016). Inadequate adoption of crop protection measure coupled with heavy infestation of insect pest and diseases adversely affects the pulse productivity (Sah *et al*., 2021).

However, real-time analysis of the effects of climatic pressures on area, productivity and the comparative performance of mitigating measures to abiotic and biotic stresses on pulses is required. The primary concern at this point is avoiding the effects of climate change and variability, which could be accomplished by avoiding, escaping and adopting Climate Resilient Agriculture (Dheebakaran *et al.,* 2020). Response farming, classified as a Climate Resilient Agriculture (CRA) technology to manage the climate variability on Indian agriculture, entails the implementation of agricultural practices guided by local meteorological information and scientific advisories. Tamil Nadu and numerous other states have previously experienced the success of responsive farming, which entails higher yield and lower risk. Technologies that are time- and location-specific have contributed to the success of responsive farming. Precision farming is made possible by response farming with timely technical guidance, which also lowers weather-related risks (Rao, 2018).

Weather-based Agro advisories from planting to harvest assist farmers plan their farm operations in advance, allowing them to maximize the productivity of their land, labor and other inputs. Furthermore, timely weather information allows resource-constrained farmers to avoid weather-related risks. In this scenario, automation using ICT tools will reduce human intervention while increasing the timely delivery of alerts (Stankovic *et al.,* 2022). On a positive note, rapid advancements in Information and Communication Technologies (ICT) have made responsive farming a realistic alternative for climate change and variability adaptation techniques. Earlier research suggested that ICT-enabled CSA technologies would be more accessible to farmers if linked to ongoing government development projects and that obstacles in technology transfer may be solved by cellular phone-based consulting services (Ireri and Daisy Mbucu., 2020).

Considering this, Tamil Nadu Agricultural University developed an ICT-enabled Web cum Mobile App called "Automated Agro Advisory Service (TNAU-AAS)" between 2015 and 2018. This app is the first of its kind in the country, which sends location, crop and stage specific weather based agromet advisories directly to registered farmers' mobile. The present study was aimed to evaluate the performance of the ICT enabled TNAU-AAS: Web cum Mobile App in pulse production under different ecosystem.

MATERIALS AND METHODS

Study area

Piloting pulse produce support system through ICT enabled services (TNAU- AAS: Web cum Mobile App) was evaluated during 2019 to 2021 in three centers of Tamil Nadu Agricultural University for three different eco systems *viz*., irrigated (ACRC, Coimbatore district), rice fallow (TRRI, Aduthurai, Thanjavur district) and rainfed (ARS, Kovilpatti, Thoothukudi district) as depicted in Fig 1. Cauvery Delta Zone (CDZ) has a total land area of 1.45 million ha, which is equivalent to 11% of the state area. In CDZ, nearly 3.1 lakh ha of Samba rice area is under rice fallow/ follow pulses and the yield realized is low compared to the potential yield obtained under irrigated conditions. Hence, there is a huge potential to increase the productivity of rice fallow pulses in this zone. Thoothukudi district is one of the important districts having more rainfed area under pulses. The area under Black gram in the Thoothukudi District is around 41319 ha (21.17% to the total area sown) and 55347 ha during 2018-19 and 2019-20 respectively. Western zone covers three districts *viz*., Coimbatore, Erode and Tiruppur districts and climatologically classified as Semi-Arid. This western zone districts is having a total pulse area of 15600 ha with a productivity of 550-600 kg/ha. Both rainfed and irrigated pulse cultivation is being practiced in this zone. In this study, irrigated pulse cultivation is targeted in Coimbatore.

Treatments

The effectiveness of disseminated advisories on various pulse producing systems was compared to that of non-TNAU - AAS users. A comparison was made for pest and disease incidence, yield and financial benefits.

1. Advisories from TNAU-AAS: Web cum Mobile App.

a. Irrigated b. Rainfed c. Rice fallow.

2. Control (No advisories).

TNAU's automated agro advisory service

TNAU-AAS is a web cum mobile application, that provides tailor made farmer's location, weather, crop and stage specific advisories, which is also directly to the farmers without human intervention and other extension functionaries. The “TNAU AAS App” has equipped with 54 weather scenarios, advisories for 108 major agricultural and horticultural crops grown in Tamil Nadu, six crop growth stages *viz*., land preparation, seedling, vegetative, reproductive, grain development and harvest. The 54 weather scenarios are combinations 6 days of past and forecasted weather, which covers possible weather conditions prevailed in Tamil Nadu. The workflow of the TNAU-AAS is depicted in Fig 2. This TNAU: AAS App helps the farmers to take necessary farming decisions, six days in advance and reduce weather risks in input and output.

Demonstration

About 26 farmers from Coimbatore (irrigated), 15 from Kovilpatti (rainfed) and 13 from Aduthurai (rice fallow) registered in the TNAU - AAS web cum Mobile App for agromet advice based response farming in blackgram between October 2019 and March 2020. Large-scale trials were conducted in ten districts (Ariyalur, Coimbatore, Erode, Pudukkottai, Thanjavur, Tiruchirappalli, Thoothukudi, Tirunelveli, Tiruppur and Virudhunagar) between October 2020 and March 2021. Among the 124 farmers involved were Bengal gram (2), Black gram (104), Rice Fallow Black gram (4), Green gram (5) and Red gram (9). Two to five non-AAS farmers from each center were included as controls in both years to compare the efficacy of the ICT enabled Agro advises. The date of sowing is not restricted because the AAS can provide advice for any season or date.

Evaluation of TNAU-AAS on plant protection

Pest and disease incidence was closely monitored in both the selected AAS and non-AAS farmers’ fields at regular intervals from 25 days after sowing to harvest by telephonic discussion with farmers. On the first appearance of pod borer, powdery mildew and yellow mosaic virus (YMV), scientists had made frequent field visits to grade the pest and disease incidence severity. Grading for powdery mildew and YMV was done by evaluating disease severity in four numbers of 20 sqm plots designated at different positions across the field. The grading scale for powdery mildew and YMV are given Table 1 and Table 2. The pod borer population per plant was also recorded from the randomly tagged 16 plants in different locations around the field. The per cent pod damage was calculated using the formula.

$$\%\ \text{Pod damage} = \frac{\text{Number of damaged pods}}{\text{Total number of pods}} \times 100$$

RESULTS AND DISCUSSION

Important agromet advisories shared from TNAU-AAS to the farmers is given in Table 3.

Irrigated pulses (Coimbatore)

Out of 26 AAS registered farmers, 16 farmers alone effectively utilized the advisories and Farmers had received 8-12 weather, crop and stage specific advisories during the crop period. Farmers who had adhered to the expert’s advice using the TNAU-AAS mobile App did not encounter a reduction in yields of crops as a result of pest and disease outbreaks. In contrast, farmers who did not use the AAS app faced damage caused by sucking pests, yellow mosaic virus (YMV) and powdery mildew. The yellow vein mosaic virus (YMV) disease increased due to favorable weather conditions for white fly (Singh *et al.,* 2018) and need prophylactic management.

The timely management by the AAS farmers for YMV through chemical spray significantly reduced the YMV and increased the grain yield compared with Non AAS farmers. In addition, the AAS farmers effectively managed the plant population by utilizing the gap filling recommendations during rainy days, resulting in increased crop yield. An average of 40-45 pods per plant was recorded in the fields of farmers who adopted the AAS method, while non-AAS farmers had an average of 36-38 pods per plant. The utilization of a 2% DAP spray, in accordance with the TNAU-AAS advice, likely had a substantial impact on maintaining the productivity of pulse crops.

Rainfed pulses (Kovilpatti)

Fifteen rainfed farmers growing black gram in Kayathar block registered in the TNAU-AAS Web Cum Mobile App for automated weather-based agro advisories, along with two non-AAS farmers, to investigate the impact of ICT-enabled services in pulses. Out of 15 registered in AAS, 10 farmers utilized advisories effectively. Kayathar block had 429 mm of average rainfall and a very healthy crop until maturity. However, constant rain during the maturity period hampered seed filling and fungal infection, lowering quality and

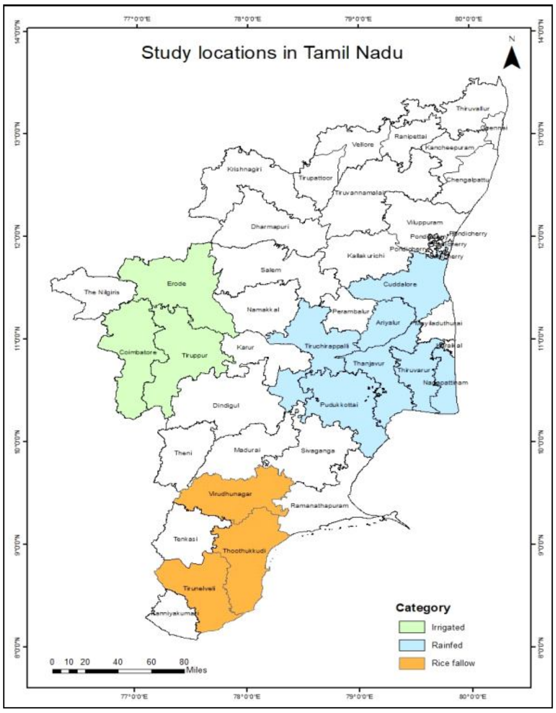

Fig 1: ICT on pulse production: Study area map.

production. Farmers who followed agromet advisories had yields of 150-300 kg/acre, while non-AAS farmers received less than 100 kg/acre. Temporary water submergence, showers during maturity and prevailing weather-based pest and disease recurrence are the key abiotic climatic vulnerabilities directly affecting black gram production in rainy season crops (Ghaffar *et al.,* 2022). It was demonstrated that establishing appropriate drainage improves development considerably in black gram cultivation, lowers the risk of water logging and related diseases and ultimately improves crop health and output. The farmers who received weather based advisories from IMD's Agro Advisory Scheme achieve improved yields through timely sowing, proactive pest and disease control and strategic fertilizer spray during the reproductive stage (Rathore *et al.,* 2008).

Rice fallow pulses (Aduthurai)

Pulse growing farmers (13 Nos.) from Aduthurai surrounding were registered in TNAU-AAS Web Cum Mobile App for automated weather based agromet advisories and they were enabled to use components namely crop management and pest and disease early warning for rice fallow pulses. Three farmers non-registered in TNAU-AAS were included as control. The economic impact has been assessed from the selected farmers after the harvest of the crop. A non-replicated experiment was also laid out in the Institute with the following treatments. Comparison of field experiment results between TNAU-AAS and non AAS farmers is given in Table 4. Adoption of AAS based crop management recorded higher (10-15%) in growth and yield parameters, which resulted in 12% higher net return and and 7% BCR compared to non AAS farmers. Early sown black gram suffers from heavy rainfall during maturity, significant yield losses due to delayed harvest, threshing and damage to grains from high moisture and sprouting. Under such conditions, adjusting the sowing time can help save the black gram crop.

Singh *et al.,* (2018) found that sowing the crop by mid-December had recorded significantly higher yields of grain. Verma *et al.*, (2023) inferred that the timely crop

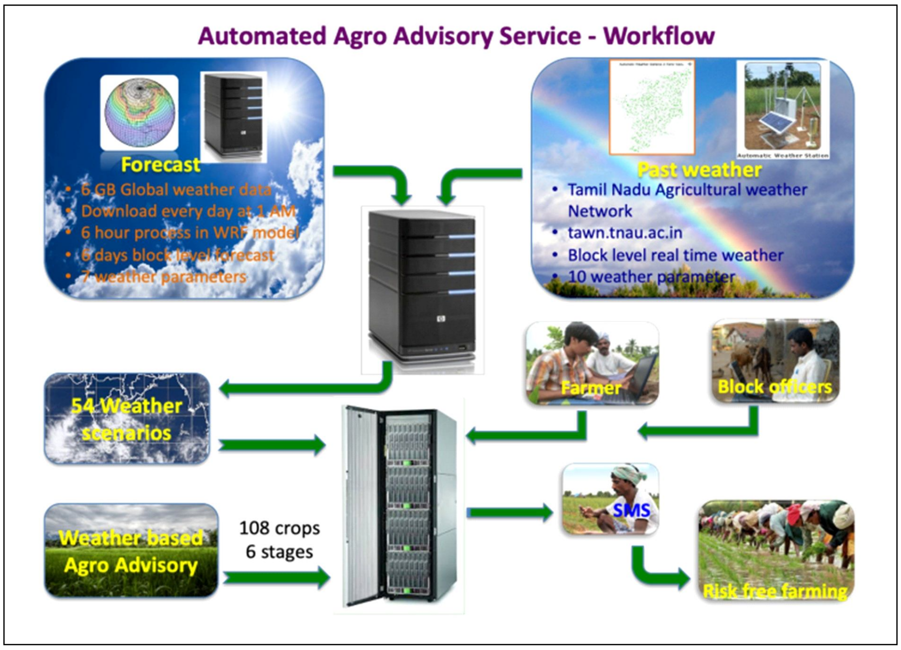

Fig 2: Workflow of TNAU-AAS Web cum mobile application. (Dheebakaran *et al.*, 2020).

Table 1: Grading scale for YMV disease severity.

Grade	Symptom
1	No visible symptoms on leaves or very minute yellow specks on leaves.
2	Small yellow specks with restricted spread covering 0.1 to 5% leaf area.
3	Yellow mottling of leaves covering 5.1 to 10% leaf area
4	Yellow mottling of leaves covering 10.1 to 15% leaf area
5	Yellow mottling and discoloration of 15.1 to 30% leaf area
6	Yellow discoloration of 30.1 to 50% leaf area
7	Pronounced yellow mottling and discoloration of leaves and pods, reduction in leaf size and stunting of plants covering 50.1 to 75% foliage
8	Severe yellow discoloration of leaves covering 75.1 to 90% of foliage, stunting of plants and reduction in pod size.
9	Severe yellow discoloration of entire leaves covering above 90.1% of foliage, stunting of plants and no pod formation

management practices such irrigation, fertilizer management, plant protection had advantages in higher yield and the magnitude of correlation vary with gram, blackgram and green gram. Similarly, improved techniques for mitigation of climatic abnormalities gave higher net returns and B:C ratio compared to control. Adoption of Recommended package of practices augmented the grain yield by 16-19% and net return by 11-19 per cent compared to Farmers' Practice. Waha *et al.* (2013) was reported the shift in sowing time can help avoid the issues faced during early sowing due to rainfall during maturity. Moisture stress mitigation techniques, such as adjusting irrigation based on weather forecasts using sprinklers, can effectively mitigate the impact of drought in rainfed farming. These measures can help ensure better crop resilience and yield stability in the face of unpredictable rainfall patterns Urruty *et al.* (2016). Maintaining plant population, implementing effective intercultural operations and pulse wonder spray can enhance the crop's resistance to drought and lead to higher productivity. These practices can help optimize the use of available resources and improve the overall health and yield of the crop.

Results of pest and disease score difference between AAS farmers and non AAS farmers is presented in Table 5. The vulnerability of non AAS farmers to the climate related risk was 66, 50 and 60 per cent more than TNAU-AAS adaptive farmer. Disease management can be effectively and economically achieved through the adoption of cultural practices, resistant cultivars, judicious use of chemicals and timely management through agro-advisory services Singh *et al.* (2019).

Table 2: Grading Scale for powdery mildew disease severity.

Grade	Description
0	Plants free from infection on leaves, stems free from the disease
1	Plants showing traces to 10% infection on leaves, stems free from the disease
2	Slight infection with thin coating of powdery growth on leaves covering 10.1-25% leaf area, slight infection on stem and the pods usually free
3	Dense powdery coating on leaves covering 25.1-50% leaf area, moderate infection on pods
4	Dense powdery coating covering 50.1-75% leaf area, stems heavily and pods moderately infected. Infected portion turns grayish
5	Severe infection with dense powdery growth covering 75% area of the whole plant including pods, stems *etc*. resulting in premature defoliation and drying

Table 3: Important advisories shared to AAS farmers for black gram cultivation.

Crop stage	Important advisories
	Irrigated pulses at Coimbatore
Vegetative	Since sufficient soil moisture is available, gap filling may be taken up to maintain population.
	Due to continuous rain and high relative humidity, powdery mildew disease may occur. Spray Carbendazim 500 g or wettable Sulphur 1500 g/ha.
Flowering	Considering the availability of soil moisture, spray 2% DAP to reduce the flower dropping and to increase seed setting.
	Rainfed pulses at Tuticorin district
Seedling	As rainfall is expected in the coming days. Provide adequate drainage in the field in order to prevent water stagnation.
Reproductive	Spray 2% DAP or 1% urea or pulse wonder to increase the crop growth if the soil moisture is optimum under rainless days.
	High RH (>90%), low temperature (15-20°C) and rainy day is conducive for leaf spot. Spray Mancozeb 2 kg or Carbendazim 500 g per hectare soon after the appearance of disease and may be repeated for every 15 days.
Pod development	Due to continuous rain and high RH, powdery mildew disease may occur. Spray Carbendazim 500 g or wettable sulphur 1.5 kg/ha.
	Rice fallow pulses at Tanjore District
Sowing time	4-6 days before rice harvest in waxy soil moisture condition.
Seed	Seed treatment with Polymer (3 ml kg^{-1} of seeds), Imidachloprid (1.5ml kg^{-1} of seeds), *P. fluorescens* (10 g kg^{-1} of seeds), rhizobium (30 g kg^{-1} of seeds) and phosphobacteria (30 g kg^{-1} of seeds).
Herbicide application	Quizalofop Ethyl 50 g ha^{-1} and Imazethapyr 50 g ha^{-1} at 15- 20 DAS when weeds are at 2- 3 leaf stage.
Foliar spray	Pulse wonder @ 5 kg ha^{-1} at flower initiation.
Stress mitigation	Mobile sprinkler irrigation at critical stages using harvested rain water from farm pond.
Plant protection	Thiamethoxam @ 100 g ha^{-1} against sucking pests, Chlorantraniliprole @ 150 ml ha^{-1} against pod borers and Carbendazim @ 250 g ha^{-1} against powdery mildew.

Table 4: Growth and yield advantage in pulses of AAS farmers over non AAS farmers.

Particulars	AAS farmer	Non AAS	Deviation %
Plant population (no. m^2)	32.6	28.1	16.0
Plant height (cm)	43.2	39.8	8.5
Dry matter production (kg ha^{-1})	2080	1802	15.4
No. of pods $plant^{-1}$	26.2	23.5	11.5
Grain yield (kg ha^{-1})	662	568	16.5
Net return (Rs. ha^{-1})	19841	17679	12.2
BCR	2.9	2.7	7.4

Table 5: Comparison of pest and disease severity scoring between AAS and non AAS farmers.

Cropping situation and	AAS farmers				Non AAS farmers			
pest and disease	1	2	3	AAS mean	1	2	3	NAA mean
Irrigated blackgram YMV grade 1-10	2.0	4.0	3.0	3.0	5.0	6.0	4.0	5.0
Rice fallow blackgram pod borer % severity	8.0	16.0	12.0	12.0	23.0	26.0	28.0	25.7
Rainfed blackgram powdery mildew grade 0-5	2.0	2.0	1.0	1.7	2.0	3.0	3.0	2.7

Table 6: Partial budgeting for black gram cultivation with TNAU-AAS.

Partial budget component	Purpose	Irrigated blackgram at Coimbatore	Rainfed blackgram at Kovilpatti	Rice fallow blackgram at Aduthurai
Added cost	DAP spray	1300/-	1300/-	1300/-
	Plant protection	4700/-	2000/-	4300/-
	Drainage	1400/-	1400/-	1100/-
Reduced return	-	Nil	Nil	Nil
Total loss		7400/-	4700/-	6700/-
Added return	Addnl. yield over non AAS farmer	10200/- (170 kg/ha)	6600/- (110 kg/ha)	9000/- (150 kg/ha)
Reduced cost	-	Nil	Nil	Nil
Total gain /ha		10200/-	4700/-	6700/-
Net gain		2800/-	1900/-	2300/-

Economic analysis

Partial budget analysis was done to assess the economic benefit by TNAU-AAS farmers over non AAS farmer and presented in Table 6. The partial budget analysis indicated that about Rs. 2800, Rs. 2300 and Rs. 1900/- have been gained by the irrigated, rice fallow and rainfed black gram farmers. Utilizing enhanced methods for addressing climate abnormalities and implementing timely pest and disease management resulted in increased net returns and a higher benefit-cost ratio for registered in TNAU-AAS web cum Mobile App compared to Non AAS farmers.

CONCLUSION

A key component of smart farming is the use of information and communication tools, especially for climate-resilient farming methods. During the cropping period, registered farmers received 10-12 timely advisories from TNAU- AAS: web cum mobile app, which allowed them to schedule crucial operations ahead of time and earn an additional income of Rs. 1900-2400 per hectare over non-registered farmers. A TNAU-AAS farmer derives benefits from increased yield, decreased input loss and decreased costs. The climate vulnerability of non-AAS farmers was exacerbated by their delayed response.

It is concluded from the study that the ICT-enabled agromet advisory system guarantees timely alerts, boosts labor and land productivity, lowers input loss and shields crops from weather-induced pests and diseases as well as climatic variability risk. Continuous improvement and upscaling of the “TNAU - AAS: web cum mobile app” through improved advisories, the inclusion of additional crops, feedback and the Artificial Intelligence module as a future course of action could increase the usefulness. Adoption of this ICT-enabled system at the national level may provide climate resilience for sustainable food production in India.

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Conflict of interest

All authors declare that they have no conflicts of interest.

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