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Mitigation and risk management of climate change in crop cultivation through the adoption of Agromet Advisory Bulletin (AAB) in NICRA adopted villages in Punjab

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सार – **फसल उत्पादन प्रबंधनीय (कृषि विज्ञान) और असहनीय (मौसम) आदानों का प्रत्यक्ष उत्पादन है। एक किसान मौसम के पूर्वानुमान का पालन करके अनियमित मौसम की स्थिति के कारण फसल उत्पादन में होने वाले नुकसान को कम कर सकता है। भारत मौसम विज्ञान विभाग जिला और ब्लॉक स्तर पर आठ मौसम प्राचलों पर मौसम पूर्वानुमान प्रदान कर रहा है। कृषि मौसम विज्ञान द्वारा-जलवायु अनुकूल कृषि में राष्ट्रीय नवाचारों पर अखिल भारतीय समन्वित अनुसंधान परियोजना के तहत, आने वाले पांच दिनों के लिए इस पूर्वानुमान का उपयोग करके एक कृषि मौसम परामर्शी बुलेटिन** (AAB) **तैयार किया जाता है और किसानों को प्रसारित किया जाता है। तीन चयनित गांवों, बदोशेकलां और बौरंगज़ेर (जिला फतेहगढ़ साहिब) और रामपुर फासे (जिला रूपनगर) में एएबी के प्रभाव का मूल्यांकन करने के लिए** 110 **किसानों का एक सर्वेक्षण किया गया था।** 110 **किसानों में से** 70 **सीमांत/छोटे किसान (भूमि जोत** < 2.0 **हेक्टेयर) थे और** 40 **मध्यम किसान** (2-10 **हेक्टेयर भूमि जोत) थे, जिन्होंने फसल की खेती में एएबी द्वारा दी गई जानकारी को अपनाया। विश्लेषण से पता चला कि चावल और गेहूं की फसलों में एएबी का पालन करने से** 65-93% **किसानों को जैविक तनाव प्रबंधन से,** 65-85% **किसानों को सिंचाई प्रबंधन से,** 75-78% **किसानों को बुआई को समायोजित करने से और** 62-65% **किसानों को पोषक तत्व प्रबंधन से लाभ हुआ। जिन किसानों ने चावल-गेहूं फसल प्रणाली में एएबी को अपनाकर अपनी फसलों के लिए सिंचाई निर्धारित की, उन्होंने डीजल को व्यर्थ जलाने से रोककर** ~ 34.2 **मीट्रिक टन** CO_2 **उत्सर्जन कम कर दिया। चावल और गेहूं की फसल में एएबी अपनाने वाले क्रमशः** 2.25-3.75 **क्विंटल/हेक्टेयर और** 1.75-4.50 **क्विंटल/हेक्टेयर की औसत उपज बढ़ाने में सक्षम रहे और व्ययकम करके क्रमशः लगभग** 4100 **से** 7000 **रुपए/हेक्टेयर और** 3200-9200 **रुपए /हेक्टेयर की बचत कर सके। इसा तरह, एएबी फसल उत्पादकता को बढ़ावा देने के साथ-साथ कार्बन फुटप्रिंट को कम करने और कृषि को पर्यावरण-अनुकूल तथा लाभदायक उद्यम बनाने में मदद कर सकता है।**

ABSTRACT. Crop production is a direct output of manageable (agronomic) and unmanageable (weather) inputs. A farmer can cut down losses in crop production due to aberrant weather conditions by following the weather forecast. The India Meteorological Department is providing a weather forecast on eight weather parameters at district and block level. Under the All India Coordinated Research Project on Agrometeorology-National Innovations in Climate Resilient Agriculture, an Agromet Advisory Bulletin (AAB) is prepared by using this forecast for the coming five days and disseminated to farmers. To evaluate the impact of AAB in three selected villages, Badoshe Kalan and Bauranga Zer (district Fatehgarh Sahib) and Rampur Fasse (district Rupnagar) a survey of 110 farmers was conducted. Amongst the 110 farmers, 70 were marginal/small farmers (landholding < 2.0ha) and 40 were medium farmers (landholding 2-10ha) who adopted the information given by AAB in crop cultivation. The analysis revealed that by following AAB in rice and wheat crops 65-93% farmers benefitted by managing biotic stresses, 65-85% farmers by irrigation management, 75-78% farmers by adjusting sowing and 62-65% farmers by nutrient management. The farmers who scheduled irrigation for their crops by adopting AAB in the rice-wheat cropping system reduced ~34.2 metric tonnes of CO_2 emissions by preventing wasteful burning of diesel. The adopters of AAB in rice and wheat crop were able to harness an average yield increase of 2.25-3.75q/ha and 1.75-4.50 q/ha, respectively and save nearly Rs 4100 to 7000/ha and Rs 3200-9200/ha, respectively with less expenditure. Hence, AAB can help boost crop productivity as well as help reduce carbon footprints and make agriculture an eco-friendly and profitable venture.

Key words – Agromet advisory bulletin (AAB), Medium range weather forecast, Crop cultivation, AICRPAM-NICRA, Punjab.

1. Introduction

The agriculture sector contributes 17-18% of GDP in India and 25% of GDP in Punjab is highly vulnerable to weather aberrations (Anonymous, 2019). The Agricultural GDP in the state of Punjab grew @ 5.7 % per year during the years 1971-72 to 1985-86, which was appreciably more than double the overall growth rate (2.31 % per year) of India. This phenomenal growth rate was by virtue of advancement in the field of agricultural production, commonly referred to as the "*Green Revolution*".

Punjab's outstanding performance had resulted in significant wheat surpluses and afterwards rice surpluses. Punjab became a symbol of India's grain surpluses, which provided the country with much-needed food security. However, in 1985-86, the green revolution began to fade, and Punjab's agricultural growth fell down to 3% per year from 1985-86 to 2004-05, nearly matching that of the rest of India. The main challenges for Punjab's agriculture came when its growth slowed to only 1.6 % per year from 2005-06 to 2016-17 which was less than half of the growth rate for India's agricultural GDP (3.6 %) over the same time. One of the major reasons for this decrement in agriculture GDP growth is inclemently weather-related aberrations (Gulati *et al*., 2021) and the high levels of crop productivity which are nearing the potential productivity of crops which are far ahead of what is seen in other states of the country. The anomalies in weather parameters (temperature, rainfall, wind speed, *etc*.) have a great impact on the agriculture sector (Jamshidi *et al*., 2018; Zobeidi *et al*., 2020). So, if a timely prediction of these parameters is available, then some of these losses can be reduced. The India Meteorological Department (IMD) is using the Numerical Weather Prediction (NWP) models for providing the weather forecast on eight weather parameters (maximum and minimum temperature, morning and evening relative humidity, wind speed and direction, rainfall and cloud cover) at district and presently at block level (Anonymous, 2022). This information can be combined with the crop management practices to prepare a holistic advisory bulletin on crop management options to be adopted in light of the weather forecast. Such bulletins can be disseminated to the farmers of the region using the available social media platforms and the farmers can tailor their day-to-day agricultural activities (*e.g*., sowing, weeding, pesticide spray, irrigation scheduling, fertilizer application, etc.) and these can help reduce the cost of crop production as well as crop loss (Chattopadya and Chandras, 2018) and can also help in reducing the damage to environment and ultimately increases crop productivity led profitability of farm income.

In present times the farmers are becoming more aware about the weather-related agricultural services available in India (Maini and Rathore, 2011; Nirwal *et al*., 2019) and abroad (Elias *et al*., 2015; Parsi and Maleksaeidi, 2021). Several Indian scientists have conducted the usability analysis of the weather forecast and also the economic impact of these advisories. Recently mobile based agro-advisory are becoming common as they have a very large outreach capability. All the workers have emphasized the usefulness of these weather-based advisories and concluded that they can be a powerful tool in enhancing farm productivity (Vashisht *et al*., 2013; Chattopadhyay and Chandras, 2018).

Agriculture is a major source as well as a sink for greenhouse gases (GHGs). The U.S. Environmental Protection Agency (EPA) reported that agriculture alone accounted for 11.2 % of GHG emissions (nearly 669.5 million metric tons of CO_2 equivalent) in U.S. during 2020 (EPA, 2020). According to the International Energy Agency, India emitted 2,299 million tonnes of CO_2 during the year 2018, which accounted for 7% of global GHG emissions. Out of total gross national emissions from India, agriculture and livestock accounted for 18 % of it (Anonymous, 2020). Scientific reports confirm that agriculture can be made carbon neutral by adopting climate smart agricultural practices such as conservation tillage, efficient water and nutrient management, etc. (Anonymous, 2021). Hence the farmer can be guided through a weather based advisory to enable them to reduce cost of production, crop loss and carbon footprints which ultimately enhances farm profitability. So, the objective of this study was to assess the impact of weather based advisory bulletins on making agriculture in Punjab state both profitable as well as eco-friendly.

2. Materials and methods

In Punjab state under the All India Coordinated Research Project on Agrometeorology-National Innovations in Climate Resilient Agriculture (AICRPAM-NICRA) two villages in Fatehgarh Sahib district, *i.e*. Badoshe Kalan (Sirhind block) and Bauranga Zer (Amloh block) and one village in Rupnagar district, *i.e*., Rampur Fasse (Chamkaur Sahib block) have been selected for which a weather based agro-advisory bulletin (AAB) is prepared in vernacular Punjabi language for the farmers. Every Tuesday of the week, the weather-based AAB containing information on weather [maximum and minimum temperature (°C), morning and evening relative humidity (%), wind speed (km/h) and direction (degree), rainfall (mm) and cloud cover (octa)] forecast and weekly activities related to agricultural crops (cereals, oilseed and pulse crops, vegetables, fruits *etc*.) are sent to selected farmers through WhatsApp and on Wednesday a printout

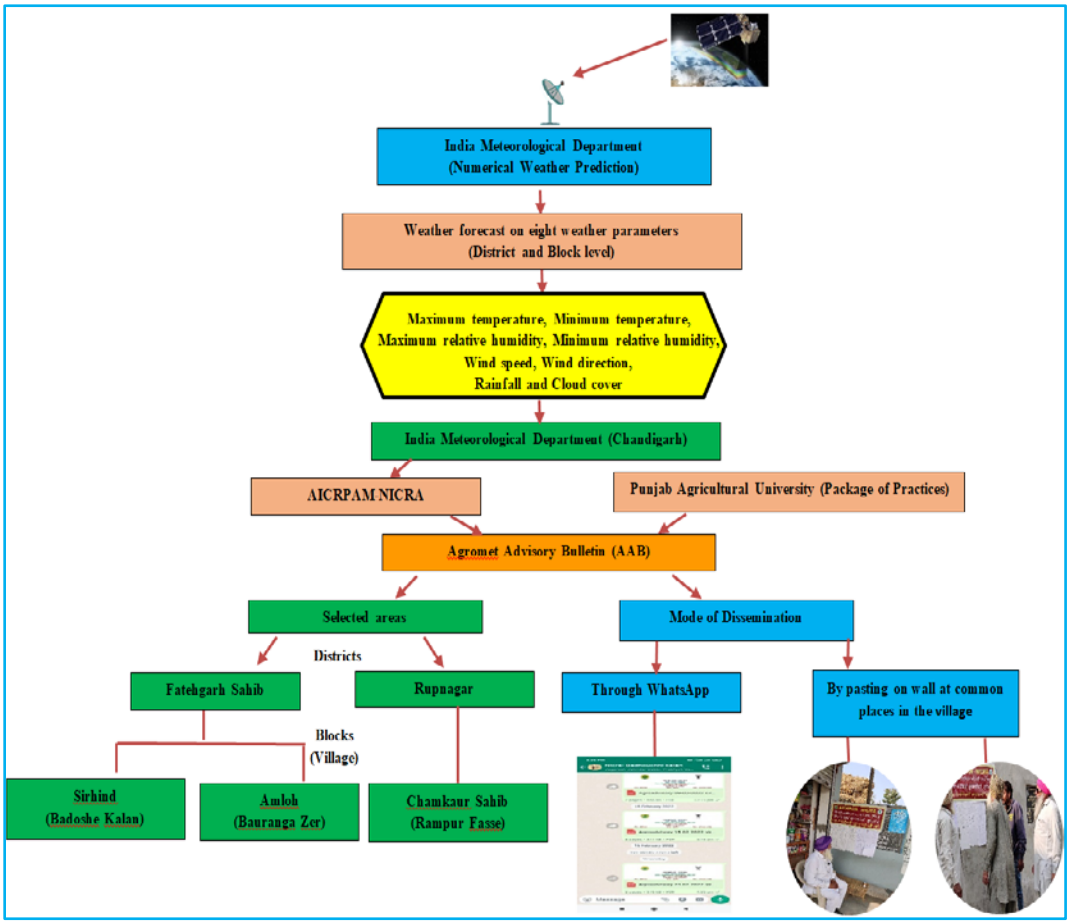

Fig. 1. Schematic illustration of generation and dissemination of AAB

of the AAB is pasted at four common sites in these villages (Fig. 1).

A survey was conducted and primary data was collected during 2021 to check out the benefits of AAB and the feedback of farmers of the AAB sent during 2020. The data was collected through personal interaction with farmer and the information was collected from a total of 110 farmers from three villages (Badoshe Kalan, Bauranga Zer and Rampur Fasse). Amongst the 110 farmer, 70 were marginal/small farmers with land holding < 2.0 ha and 40 were medium farmers with land holding 2 - 10 ha who were invariably practicing the rice-wheat cropping system. The selected farmers had adopted the weather-based information given by the AAB provided a weekly basis during their crop raising period as per their individual needs and resources. To estimate the cost of cultivation of paddy and wheat crop for different categories of farmers, the data was statistically analysed to calculate the benefits that the farmers got by following the advisory w.r.t. crop management (appropriate sowing / harvesting time, land preparation, nutrient and water management, pest and weed control *etc.*). The income generated by the farmers was calculated by considering the minimum support price (MSP) fixed on the recommendations of the Commission for Agricultural Costs and Prices (CACP) for rice and wheat during the year 2020-21. The descriptive statistical analysis of the data was done to evaluate the level of significance of the benefit accrued by the adopters over the non-adopters. The reduction in carbon dioxide (CO_2) emissions from need based irrigation of crops in Punjab state is invariably done by burning diesel fuel to operate tube-well irrigation pumps etc. has been estimated in the analysis of the data. By burning 1 litre of diesel 2640 g of CO_2 emission takes place which is calculated with the methodology available at https://ecoscore.be/en/info/ecoscore/co2:

Weight of 1 litre of diesel = 835 g

Carbon constitution in diesel = 86.2%

So, weight of carbon in 1 litre of diesel = 720 g

TABLE 1

Socio-economic and general perception of selected farmers from three villages in Punjab

Parameters		No. of respondents/110	Percentage (%)
Total farmers	110		
Age (years)	18-70		
Education	Middle to Graduate		
Crop	Rice -Wheat		
Do you watch or listen to advisories?	Yes	110	100
	No	-	-
Are advisory giving benefits to you?	Yes	108	98.2
	No	02	1.8
Do you think weather-based farm advisories are helpful in increasing your income and yield?	Yes	104	94.5
	No	06	5.5
Any loss faced due to advisories?	Yes	07	6.4
	No	103	93.6
Do you think, weather-based programme should be organized in your village from time to time?	Yes	110	100
	No	-	-

TABLE 2

Economic impact analysis of the farmers adopting the Agromet advisory bulletin (AAB) during the rice cropping season

Crop management practices	Number of adopters		Area under adoption (ha)	Total adopters and non-adopters		Yield (q/ha)		Income (#) (Rs/ha)		Expenditure (Rs/ha)	
	Marginal/small farmers (<02 ha) (70)	Medium farmers (02-10 ha) (40)		Adopters	Non-Adopters	Adopter	Non-Adopter	Adopter	Non-Adopter	Adopter	Non-Adopter
Sowing time	54 (77.1%)	29 (72.5%)	201.30	83	27	66.50	63.00**	1,25,529	1,19,180**	-	-
Nutrient management	41 (58.5%)	31(77.5%)	95.60	72	38	64.75	62.50**	1,22,235	1,18,038**	2,350	5,070**
Weed control	38 (54.3%)	20 (50.0%)	156.90	58	52	67.50	63.75**	1,27,390	1,20,340**	2,240	1,550**
Insect and disease control	63 (90.0%)	39 (97.5%)	245.10	102	8	-	-	-	-	5,950	8,040**
Irrigation scheduling	60 (85.7%)	33 (82.5%)	211.30	93	17	-	-	-	-	6,970	10,720**

** (Significantly difference at $p \leq 0.01$)
# Minimum support price of rice during 2020 – Rs 1,888/quintal

Since, to combust this 720 g of carbon into CO_2, 1920 g of oxygen is needed

Therefore, total weight of CO_2/litre diesel = 720 + 1920 = 2640 g

The timely and need based application of irrigation water, nutrients, weedicide, pesticide etc. led to an increase in crop yield, saving of monetary resources as well as a reduction in carbon footprints due to less emission of greenhouse gases (carbon dioxide, methane and nitrous oxide).

TABLE 3

Economic impact analysis of the farmers adopting the Agromet advisory bulletin (AAB) during the wheat cropping season

Crop management practices	Number of adopters		Area under adoption (ha)	Total adopters and non-adopters		Yield (q/ha)		Income (#) (Rs/ha)		Expenditure (Rs/ha)	
	Marginal/small farmers (<02 ha) (70)	Medium farmers (02-10 ha) (40)		Adopters	Non-Adopters	Adopter	Non-Adopter	Adopter	Non-Adopter	Adopter	Non-Adopter
Sowing time	55 (78.6%)	31 (77.5%)	215.3	86	24	46.50	43.00**	91,345	86,405**	-	-
Nutrient management	44 (62.8%)	25 (62.5%)	155.6	69	41	47.75	46.00**	94,280	91,040**	4,915	6,585**
Weed control	58 (82.8%)	32 (80.0%)	221.8	90	20	49.00	44.50**	97,075	87,835**	1,510	1,250**
Insect and disease control	46 (65.7%)	26 (65.0%)	154.3	72	38	-	-	-	-	1,050	1,370**
Irrigation scheduling	46 (65.7%)	25 (62.5%)	102.3	71	39	-	-	-	-	4,250	5,575**

** (Significantly difference at $p \leq 0.01$)
# Minimum support price of rice during 2020-21 – Rs 1,975/quintal

3. Results and discussion

Socio-economic status of the AAB adopter farmers

The socio-economic status of the farm households has a differential impact on their awareness about the availability and usefulness of the AAB and hence their keenness to adopt. The results revealed that the education level of the selected farmers (age group of 18 to 70 years) varied from middle to graduate level and were practising the rice-wheat cropping system (Table 1). All the selected farmers were either watching or listening to AAB and 98% reported to have found AAB useful and 93.6% believed that AAB was helping in increasing the yield of rice and wheat crops. Only 6.4% of the farmers were reported to have suffered loss due to the wrong forecast given by the AAB. In a similar studies on agromet advisory services in different states of India conducted by Singh *et al.* (2015) in Meghalaya, Dupdal *et al*. (2020) in Karnataka and Andhra Pradesh, Kumar *et al.* (2021) in Ladakh, Praveen *et al.* (2022) in Karnataka also reported that the education level of farmers was an important trigger for creating willingness to adapt the news aids for improving their farm productivity and age of the adopter added to his experience in farm practices.

Sources of weather based advisory for farmers in Punjab

The farmers in Punjab state have access to different social media platforms and are closely linked to Krishi Vigyan Kendras (KVKs) and the State Agricultural Department. The selected farmers reported that they generally followed the weather-based advisory issued under the AICRPAM-NICRA project (60%), newspaper/television/ radio (20%), KVKs (15%) and the State Agriculture Department (5%). In India the weather-based advisory is being provided to farmers under the AICRPAM-NICRA (funded by Indian Council for Agricultural Research) and GKMS (Gramin Krishi Mausam Sewa) (funded by India Meteorological Department, Ministry of Earth Sciences) projects and several studies conducted in the country have reported that Indian farmers are using the information given in these advisories to tailor their farming practices (Chattopadya and Chandras, 2018; Prabha and Arunachalam, 2021).

Frequency of adopter's vs non adopters of AAB in Punjab

The frequency of farmers who adopted AAB and non-adopters of AAB in marginal (land holding < 2.0 ha) and medium (land holding 2-10 ha) sized category of selected farmers in the three villages were analyzed. Amongst the three villages, the adoption of AAB during rice crop season in village Badoshe kalan was 73.4 and 80.3% by marginal/small and medium farmers, respectively; in village Bauranga zer was 74.2 and 75%, respectively by marginal/small and medium farmers, respectively and in village Rampur fasse was 71.8 and 72.4% by marginal/small and medium farmers,

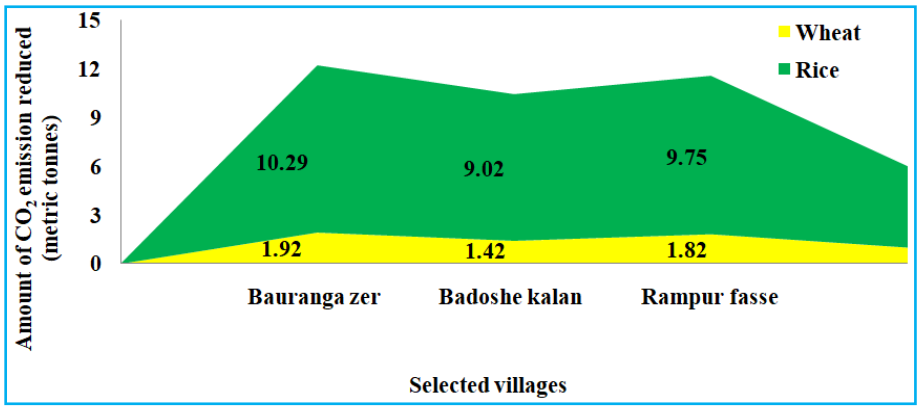

Fig. 2. Estimated reduction in CO_2 emission from fields of AAB adopters in three selected villages in Punjab

respectively. Similarly, during the wheat season the adoption of AAB in village Badoshe kalan was 69.7 and 69.6% by marginal/small and medium farmers, respectively; in village Bauranga zer was 69.2 and 72.0% by marginal/small and medium farmers, respectively and in village Rampur fasse was 68.5 and 66.1% by marginal/small and medium farmers, respectively. Hence the overall response of farmers in the three villages for adoption of AAB during the rice season was 71-80% and during the wheat season was 66-72% by farmers. In earlier studies conducted by several workers in the country also reported the good response by farmers towards adoption of agro-advisory in scheduling of farm operations (Maini and Rathore, 2011; Vashisht *et al.*, 2013; Khobragade *et al.*, 2014 and Kumar *et al*., 2021).

Economic impact assessment of AAB in Punjab

The farmers who tailored their respective farm operations in accordance with the AAB were able to increase the yield of rice and wheat crops (Tables 2 and 3). Amongst the two categories of selected farmers, the AAB advisory was followed for sowing time operations by 72-77 and 77-79% farmers in rice and wheat, respectively; for nutrient management by 58-77 and 62% farmers in rice and wheat, respectively; for weed control by 50-54 and 80-82% farmers in rice and wheat, respectively; for insect and disease control by 90-97 and 65% farmers in rice and wheat, respectively and for irrigation scheduling by 82-85 and 62-65% farmers in rice and wheat, respectively. The statistical analysis of the data showed that adopters of AAB reported an increase in rice yield by 2.25-3.75 q/ha and in wheat yield by 1.75-4.50 q/ha over the non-adopters. The rice and wheat yield realized by the adopters of AAB was in the range of 64.75-67.50 and 46.50-49.00 q/ha, respectively and it was significantly ($p \leq 0.01$) higher than the non-adopters. Consequently the income generated by the adopters of AAB for rice and wheat growers was significantly ($p \leq 0.01$) higher by Rs 4100-7000/ha and Rs 3200-9200/ha, respectively. Interestingly non-adopters of AAB spent lesser money on spraying recommended weedicide on rice and wheat which ultimately reduced their yields by 3.75 and 4.50 q/ha, respectively. The timely and need based spraying of pesticides for controlling insect and disease attack resulted in net saving of Rs 2090/ha in rice and Rs 320/ha in wheat crop. The optimised irrigation scheduling can be done by considering the stage of the crop and prediction of rainfall (if any) and the adopters of AAB were able to save Rs 3750/ha in water guzzling rice crop. In the case of wheat crop, farmers tend to frequently irrigate the crop so the AAB followers were able to save Rs 1325/ha by applying only AAB recommended irrigation scheduling. Ray *et al*. (2017) reported an additional benefit of 41.2 %, 20.8% and 34.8 % in green gram, rice and maize crops, respectively by the followers of advisory in Odisha. In the states of Andhra Pradesh and Karnataka the adopters of the advisory bulletin were getting 12-33% increase in their profits (Dupdal *et al*., 2020).

Positive impact of AAB in reducing the carbon footprints

The adopters of AAB were able to cut down the consumption of fossil fuel (diesel) by timely and need based applications of irrigation water to crops especially water guzzling rice. In Punjab state the farmers are advised to irrigate their rice fields after the water has percolated in the soil since it not only saves the irrigation water but also reduces the emission of methane gas. The emission of carbon dioxide (CO_2) gas by burning of fossil fuel has been estimated as per the methodology explained by Hossain and Chen (2021). From the three selected villages Bauranga Zer, Badoshe Kalan and Rampur Fasse by virtue of adoption of AAB, the CO_2 gas emissions were

reduced by 10.30, 9.02 and 9.75 metric tonnes per village, respectively during the rice season and by 1.92, 1.42 and 1.82 metric tonnes per village respectively during the wheat season (Fig. 2). So, a net reduction in CO_2 gas emissions of nearly 34.2 metric tonnes was estimated with simply the need-based burning of fossil fuel to operate the pumping sets for irrigating the rice and wheat crop during the study period 2020.

4. Conclusions

The results of the present study have shown that the adopters of the AAB were able to increase their rice and wheat productivity by 2.25-3.75 and 1.75-4.50 q/ha, respectively, by tailoring the crop management in the climate smart mode, *i.e.*, scheduling land preparation/ timely sowing, spraying of weedicides/pesticides as per the predicted weather for coming 4-5 days. The analysis of the study revealed that adopters using AAB could generate more income due to the higher yield of crop, *i.e.*, by Rs 4100-7000/ha in rice crop and by Rs 3200-9200/ha in wheat crop. The expenditure done by the adopters of AAB was Rs 690-3750/ha on rice and Rs 320-1670/ha on wheat was significantly lower ($p \leq 0.01$) than the non adopters. The farm inputs such as seed, fertilizer, irrigation water, biotic stress management inputs, etc. are becoming costlier and so their scientific application and judicious management can reduce the input cost which actually enhances cost / benefit ratio.

Environmental pollution and degradation of soil and air can be reduced by need based spraying of pesticides and also by judicious application of irrigation water. Over and wasteful irrigation of a crop results in additional burning of fossil fuel, *i.e.*, diesel used for operating the irrigation pump systems. In the present study, it was estimated that 29.1 metric tonnes of CO_2 emissions were reduced from 211.3 ha of rice cropped area by the adoption of AAB alone by the farmers. During 2019-20 rice was cultivated on an area of 3.14 Mha in Punjab. So, if all the farmers who were cultivating rice had been irrigating their fields by adopting the weather based advisory, then approximately 0.43 million metric tonnes of CO_2 emissions could have been checked. So, the benefits of adopting weather based agromet advisory will not only make agriculture profitable but also climate friendly.

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