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Economic Impacts of Weather Forecast Based Advisories on Vegetable Crops in Mid-hills of Himachal Pradesh, India

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ABSTRACT

The present investigation was conducted from January, 2022 to December, 2023 in Solan district of Himachal Pradesh under the Department of Environmental Science, Dr. Y.S. Parmar University of Horticulture and Forestry, Nauni, Himachal Pradesh, India to evaluate the economic impact of Agromet Advisory Services (AAS) on major vegetable crops in the mid-hill region. Five blocks, namely Solan, Kandaghat, Dharampur, Kunihar and Nalagarh were selected for the study. From each block, ten AAS adopters and ten non-AAS farmers were randomly selected, making a total sample of 100 farmers. Forecast verification for the period 2016–2023 revealed that the highest annual usability was observed for morning relative humidity (79.4%), followed by minimum temperature (77.0%) and rainfall (73.8%), indicating the reliability of medium-range weather forecasts for farm-level applications. The economic analysis showed that AAS adopters achieved significant savings in input cost (6–8%) due to need-based irrigation, optimized fertilizer application and timely plant protection measures. Consequently, higher net returns were recorded in tomato (11.1%), capsicum (10.3%), cauliflower (9.8%) and pea (8.9%) compared to non-AAS farmers, who experienced net losses ranging from 9 to 12% under similar climatic conditions. The advisories also helped in reducing weather-induced risks, improving resource-use efficiency and enhancing crop productivity. The study clearly indicates that the integration of weather-based agromet advisories into farm management decisions enhances economic profitability, strengthens climate resilience and promotes sustainable vegetable production in the mid-hill agro-ecosystem of Himachal Pradesh.

KEYWORDS: Agromet advisory, crop economics, vegetable production, input efficiency

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1. INTRODUCTION

Recurrent extreme weather events pose serious threats to human food security under the changing climate scenarios. Situated within South East Asia's monsoon region, India includes Himachal Pradesh (Rana et al., 2013; Gautam et al., 2004) is one of the major climatically vulnerable regions which frequently experiencing weather vagaries calamities. There was an exponential increase in extreme weather events in India during 1970–2019; with a remarkable acceleration from 2000 to 2019 period especially as > 75% districts of the country are prone to different climatic hazards (Balet al., 2021). The crop yield is highly sensitive to weather vagaries as over a third of global crop yield variability is being explained by different weather parameters (Rayet al., 2015; Vogel et al., 2019). The plants have a typically narrow climatic requirement range for optimal growing conditions; any deviation from this range affect their growth drastically (Lobellet al., 2012; Siebertet al., 2017) or even totally collapsed (Luo, 2011; Devi et al., 2020). More importantly, the extreme weather events like cloud amounts, flood, drought, dry spells, ground frost, different storms and other weatheraberrations cause obvious impact and have significant influence on agricultural management decisions and hence, cost of cultivation (Singh et al., 2020; Singh et al., 2022). Understanding the importance of coming weather signal cause crop yield variations is the need of the hour to adapt agricultural production systems to climate change (Frieler et al., 2017). The meteorological forecasting and disaster early warning with sufficient lead time plays a pivotal role in agricultural production, storage, transportation, also effectively empower farmers to withstand these extremes and alleviate poverty with improved economic status. However, quantifying the agricultural value of weather forecasting services remains a major challenge.Several workers have conducted studies on the values of meteorological forecasting in agriculture in different regions of the world (Petersen and Fraser, 2001; Cantelaube and Terres (2005); Robinson and Butler, 2002; Roudier et al., 2014; Tesfaye et al., 2019; Ray et al., 2017; Singh and Bhardwaj, 2012). Timely agromet advisories (Stigter, 2011) can save money on inputs, labour and the produce itself. Agrometadvisory services (AAS) as farmers 'weather bulletin by the India Meteorological Department was launched in 1945 and with partnership of different state agricultural departments in 1976. Since 1991, the National Centre for Medium Range Weather Forecast (NCMRWF) is providing quantitative regional specific weather forecasts with a spatial resolution of 250 km in the medium range (3 days). In 1993, the spatial resolution was improved to 150 km, further in 1999 to 75 km and the temporal resolution was extended from 3 to 5 days in 2006. The AMFU was 5 in 1991 grew to 130 units to cover all the agroclimatic zones of India. The two systems of weather forecast i.e. MD and NCMRWF were combined into one single system in 2007. The IMD started proving multi–model ensemble weather forecasts (50 km spatial resolution and 5–day temporal resolution) at the district level on 1 June 2008 and block/taluka level in 2018 bi-weekly. Based on this weather forecast agromet advisories are being prepared and disseminated on every Tuesday and Friday for all the agriculturally important districts (~700) and around 3100 blocks by 130 AMFUs and 199 DAMUs which is also available on mobile App viz., 'Meghdoot' and 'Kisan Suvidha'. More than 98% of farmers (3,965 farmersin121 districts of 11 states) modify at least one of nine practices based on weather based advisories (Anonymous, 2020). The present study was conducted under AMFU Solan district (HP) on two categories of farmers i.e. 10 AAS and 10 Non-AAS from each of five blocks of the district to assess the impact of AAS on crop economy (tomato, capsicum, cauliflower, and pea) in the mid hill region of Himachal Pradesh.

2. MATERIALS AND METHODS

2.1. Study area

This investigation was conducted during Jan, 2022–Dec, 2023 in five blocks viz. Solan, Kandaghat, Dharampur, Kunihar, and Nalagarh of district Solan (30° 54' 21.24'' N, 77° 5' 33'' E with average 1600 m amsl). The district (Figure 1) was representing the mid hill region of Himachal Pradesh. The climate wassub-tropical to sub-temperate and semi-humid, marked by cold winters and four distinct seasons.

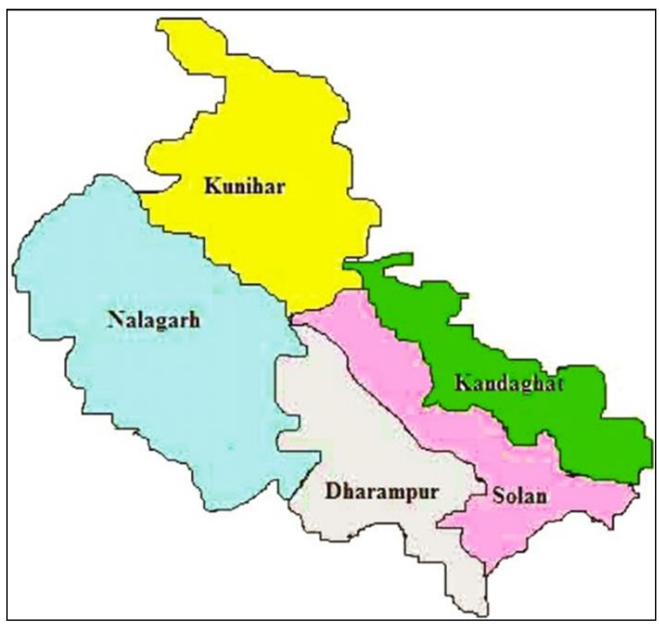

Figure 1: Solan district with five blocks

2.2. Selection of respondents and crops

From each block, a sample size of 100 respondents (10 AAS and 10 Non AAS) was selected for the collection of primary data. Farmers who were assessing and adopting the medium range weather forecast based agromet advisories issued by AMFU were termed as AAS farmers while those was not caring about agromet advisory bulk dissemination were termed as non-AAS farmers.The commercially important crops of the district viz. tomato, capsicum, cauliflower, and pea were selected for the study. These crops were chosen due to their significance in the area's agricultural practices and their representation of varying seasonal and input requirements.

2.3. Data collection and analysis

The primary data was collected from the selected AAS and Non-AAS farmers of both the categories through a well structured questionnaire. The data encompassed details about cropping patterns and the cost of cultivation (inputs and outputs). The variable cost of inputs included (field preparation, sowing, transplanting, fertilizers, manure, intercultural operations, plant protection, irrigation, labours and harvesting) outputs costs (yield, selling price,gross returns, net profit). The comparative analysis between AAS and Non-AAS farmers was conducted to evaluate the impact of agro-advisory services on the economic returns of selected crops.

2.4. Weather forecast verification

The quantitative local specific medium range weather forecast was verified for four seasons. In this regard, a usability analysis of the forecasts was performed in three categories,i.e. correct, usable and unusable, based on the forecast and observed values for different weather parameters (rainfall temperature and RH) using the critical error structure (Table 1) from the period of 2016–2023.

2.4.1. Qualitative analysis of rainfall forecast

Based on the 2×2 contingency table, the ratio score and Hanssen and Kuipers (H.K.) or true skill score were determined for qualitative analysis of the rainfall forecast by using the following formulae (Kaur and Singh, 2019):

Forecast/Observed	Rain	No Rain
Rain	A (YY)	B (YN)
No Rain	C (NY)	D (NN)

Where,

A=No. of hits (predicted and observed)

B=No. of false alarms (predicted but not observed)

C=No. of misses (not predicted but observed)

D=No. of correct predictions of no rains (neither predicted nor observed)

2.4.1.1. Forecast accuracy (acc) or ratio score

It is the ratio of correct forecasts to the total number of forecasts.

Ratio score=(CorrectForecast/TotalForecast)= (A+D)/N =(YY+NN)/(YY+NN+YN+NY)

2.4.1.2. Hanssen and Kuipers Scores or True Skill Score (HK Score)

It is the ratio of economic saving over climatology due to the forecast to that of a set of perfect forecasts. It ranges from -1 to +1.

HK=(CorrectForecast-(Correctforecast)random)/(N-(Correctforecast)random,unbaised)

HK=(ACC)event+ (ACC)non-event -1 =(AD-BC/((A+C)(B+D))

3. RESULTS AND DISCUSSION

3.1. Verification of medium range weather forecast

3.1.1. Verification of rainfall forecast

The annual accuracy of rainfall forecast at Solan was 65.3 and 69.0% during 2021–22 and 2022–23 which increased to 70.1% during 2023–24 (Figure 2) which might be attributed to the advancement in data processing techniques and better monitoring and modeling systems at forecast level. The highest correct rainfall forecast (94.2%) was during post monsoon season followed by winter season (88.5%) and the lowest (34.3%) during SWM season which also received maximum rainfall. Kaur and Singh (2019) also reported that rainfall predictions were highly erratic during the monsoon season in western Indo-Gangetic plain.

The skill score analysis of rainfall forecast was done with respect to Ratio Score (RS) and Hanssen and Kuipers scores (HK) for four seasons (Table 2). The winter season showed the most skilful forecast followed by post monsoon in terms of both the scores. The ratio score was highest during the

Table 1: Critical values oferror structure for usability analysis of weather forecasts

Categories of error structure	Weather parameters		
	Rainfall (mm)	Temperature (°C)	Relative humidity (%)
Correct	Diff ≤0.2 mm	Diff ≤1.0°C	Diff ≤10%
Usable	0.2 mm<Diff ≤2.0 mm	1.0 °C < Diff ≤ 2.0°C	10%< Diff ≤ 20%
Unusable	Diff >2.0 mm	Diff >2.0°C	Diff >20%

Diff: Absolute difference between observed and forecasted; Obs: Observed

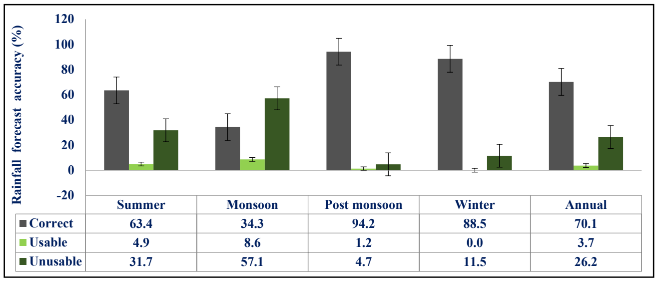

Figure 2: Seasonal usability of rainfall forecast in Solan district

Table 2: Skill score analysis of rainfall forecast for Solan district

Seasons	Ratio score (%)	Heinsen and Kouper's (HK)
Summer	67.2	0.44
Monsoon	57.4	0.32
Post monsoon	93.5	0.67
Winter	95.6	0.95

winter (95.6%) followed by post-monsoon season (93.5%) but lowest during monsoon season (57.4). Similarly, the HK score was highest during winter (0.95) followed by post-monsoon season (0.67) and lowest during monsoon season (0.32). Similar seasonal variability in rainfall forecast skill, with lower accuracy during the monsoon due to convective uncertainties, has been reported for different agroclimatic regions of India (Kaur et al., 2024; Singh et al., 2022; Kumar et al., 2021). These studies emphasized that improved model resolution and data assimilation have enhanced post-monsoon and winter forecast performance in recent years.

3.1.2. *Verification temperatures forecast*

The annual accuracy of the maximum temperature forecast was 40.4% correct, 23.7% usable and 35.9% was unusable (Figure 3a). The verification of forecasted to the observed maximum temperature was highest correct for post monsoon season (49.0%) followed by SWM monsoon (45.0%) and the lowest for summer season (28.0). Similarly, the annual accuracy of minimum temperature was 52.0 with the highest correct during monsoon season (56.6%) followed by winter (55.0%) and summer season (50.8%) and the lowest during the post-monsoon season (45.0%), respectively (Figure 3b). Rana et al. (2013) also found that the post-monsoon season had a high degree of relationship between predicted and observed values temperatures. The comparatively higher accuracy of minimum temperature forecasts than maximum temperature is consistent with recent studies, which reported better model performance for night-time temperature due to lower atmospheric variability (Kaur et al., 2024; Singh et al., 2022). Similar results for the north-western Himalayan region were also documented by Kumar et al. (2021).

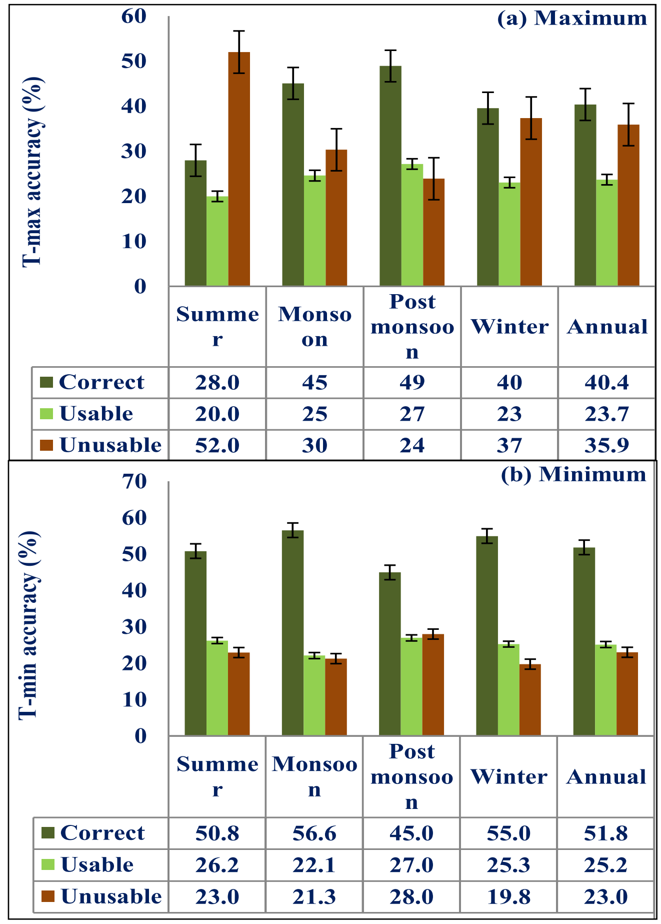

Figure 3: Seasonal usability of temperatures forecast in Solan district

3.1.3. *Verification relative humidity forecast*

The annual verification of morning relative humidity showed that the value of correct forecast was 54.3%; usable 25.0%and unusable 20.6% (Figure4a). Among the seasons the correct forecast was obtained highest during the monsoon season (72.1%) and lowest during the summer season (23.0%). The usable forecast was highest during summer season(34.4%) but the unusable in summer season (42.6%). The annual verification of evening relative humidity was 41.7% correct, 29.2% and 29.1% was usable (Figure 4b). Among the seasons the correct forecast was obtained highest (48.9%) during post-monsoon season followed by winter (47.3%). The lowest correct and highest unusable forecast was during summer (31.2%) and having highest unusable forecast of 37.7% in the year 2023–24 (Figure 3b). Higher forecast skill during the monsoon season for morning relative humidity has also been observed in recent agrometeorological verification studies, which attributed this to stable moisture regimes during the rainy season (Kaur et al., 2024; Pradhan et al., 2023; Singh et al., 2022).

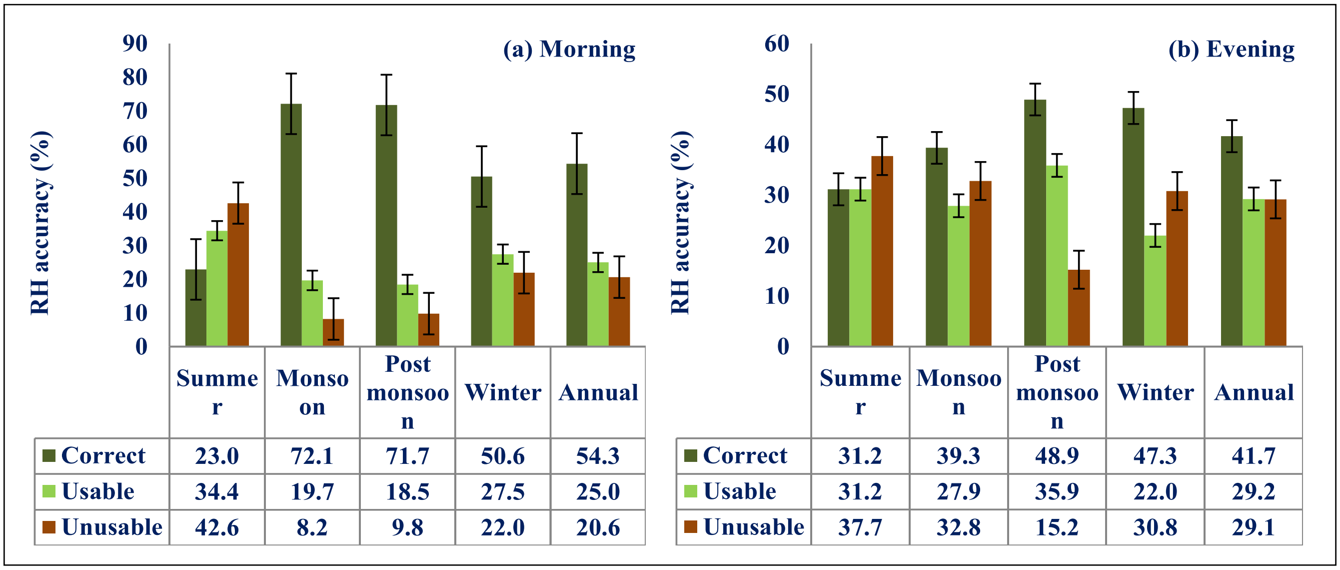

Figure 4: Seasonal usability of relative humidity forecast in Solan district

3.2. Crop economy assessment

The collected data on inputs and outputs was analyzed to assess the impact of weather forecast based agromet advisories on the economy of the important crops (tomato, capsicum, cauliflower and pea) in five blocks (Solan, Kandaghat, Dharampur, Kunihar, and Nalagarh) of Solan District representing the mid hill region of Himachal Pradesh. The results obtained are being discussed crop wise in the following headings:

3.2.1. Tomato crop

For the cultivation of tomato the percent saving of different inputs incurred to the AAS farmers and losses to the Non-AAS farmers were given in Table 3. The maximum saving was observed for irrigation (25.8%) in Kunihar block (B_4) followed by manure (20%) in Solan block (B_1) and the minimum was for pesticides (2.2%) in Dharampur block followed by harvesting (3.9%) in Kandaghat block. The AAS farmers also incurred some losses for some inputs like for harvesting (6.6%) in Solan block and for labours (4.4%) in Kandaghat block. The cost of seed was at par with the Non-AAS farmers in B_1, B_2, B_3 and B_4 but observed 7%saving in B_5 (Table 3). The higher net returns and reduced cost of cultivation among AAS farmers were mainly due to need-based irrigation, optimized input use and timely plant protection measures. Comparable economic gains

Table 3: Cost of cultivation of tomato incurred to AAS and Non-AAS farmers in five blocks of Solan district

Operations/ Quantity		Saving or loss (%)											
		AAS farmers						Non-AAS farmers					
		B_{1*}	B_2	B_3	B_4	B_5	Mean	B_1	B_2	B_3	B_4	B_5	Mean
Input	a) Field	13.6	7.0	7.4	10.9	13.0	10.4	-12.0	-6.5	-6.9	-9.8	-11.5	-9.4
	b) Seed	0.0	0.0	0.0	0.0	7.0	1.4	0.0	0.0	0.0	0.0	-6.6	-1.3
	c) Manure	20.0	17.8	18.2	12.7	9.8	15.7	-16.7	-15.1	-15.4	-11.3	-8.9	-13.5
	d) Pesticide	6.5	17.4	2.2	6.4	7.1	7.9	-6.1	-14.8	-2.1	-6.0	-6.6	-7.1
	e) Irrigation	12.1	25.0	14.0	25.8	15.9	18.5	-10.8	-20.0	-12.2	-20.5	-13.7	-15.4
	f) Labour	5.4	-4.4	-3.0	8.1	13.6	3.9	-5.1	4.6	3.1	-7.5	-12.0	-3.4
	g) Harvesting	-6.6	3.9	14.0	9.1	7.4	5.6	7.0	-3.8	-12.3	-8.3	-6.9	-4.9
Total (a-g)	6.8	11.3	8.9	8.7	9.0	8.9	-6.4	-10.2	-8.2	-8.0	-8.2	-8.2	
Output	Yield (q ha^{-1})	4.5	2.8	4.6	4.1	1.0	3.4	-4.7	-2.9	-4.8	-4.3	-1.0	-3.5
	Gross return	4.6	3.6	4.0	3.4	3.9	3.9	-4.8	-3.7	-4.2	-3.5	-4.0	-4.0
	Net profit	11.8	12.4	10.0	10.8	10.6	11.1	-13.3	-14.2	-11.1	-12.0	-11.8	-12.5

*B_1: Solan; B_2: Kandaghat; B_3: Dharampur; B_4: Kunihar; B_5: Nalagarh

ranging from 8–15% due to agromet advisories have been reported in different cropping systems (Kaur et al., 2024; Kumar et al., 2021; Singh et al., 2022).

The non-AAS farmers were incurred highest extra cost in term irrigation (20.5%) in Kunihar block followed by Kandaghat block (20.0%) and for manure (16.7%) in Solan block which indicated the impact of agromet advisories in scheduling of irrigation and manuring applications. In total 8.2 % extra cost was incurred to the non-AAS tomato grower in the district. In the tomato cultivation, on an average the AAS farmers were able to save 8.9% of inputs costs and gained 11.1% net profit whereas non-AAS farmers was incurred with 8.2% higher input cost with net loss of 12.5% (Figure 5). This indicated a clear impact of agromet advisories on the tomato crop economy to the growers. Similar results were obtained by Dupdal et al. (2020) and Kumar et al., (2021) who attributed to the timely adoption of agromet advisories and better crop management practices based on them.

3.2.2. Capsicum crop

For the cultivation of capsicum the percent saving of different inputs incurred to the AAS farmers and losses to the Non-AAS farmers were given in Table 4. The maximum saving was observed for labour (23.8 %) in Nalagarh block (B_5) followed by irrigation (23.4%) in Solan block (B_1) and the minimum was for pesticides (0.3%) in Solan block followed by irrigation (2.1%) in Nalagarh block. The AAS farmers also incurred some losses for some inputs like for irrigation (6.1%) in Dharampur block (Table 4). The non-AAS farmers were incurred highest extra cost in term labour (19.2%) in Nalagarh followed by Solan block

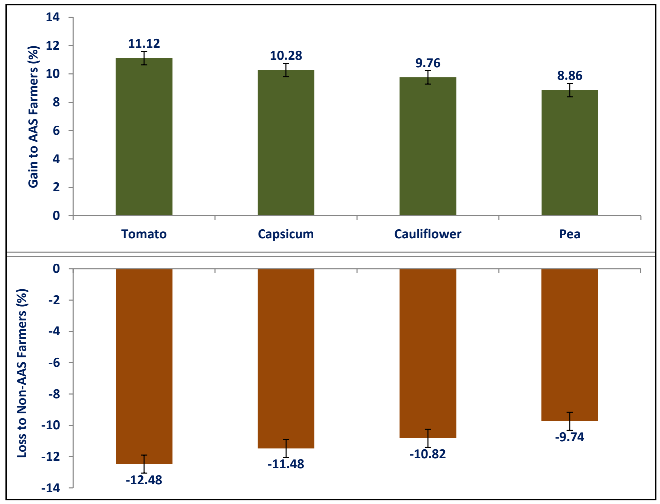

Figure 5: Gain and loss incurred to AAS and Non-AAS farmers from different crops in mid hill region of Himachal Pradesh

(18.9%) for irrigation and for labour (18.4%) in Dharampur block which indicated the impact of agromet advisories in scheduling of irrigation applications. In total 6.2% extra cost was incurred to the non-AAS capsicum grower in the district. In the capsicum cultivation, on an average the AAS farmers were able to save 6.7% of inputs costs and gained 10.3% net profit whereas non-AAS farmers was incurred with 6.2% higher input cost with net loss of 11.5% (Figure 5). This indicated a clear impact of agromet advisories on the capsicum crop economy to the growers, which may be due to the fact of higher variations in input cost or productivity differences amongst the farmers who did not utilize the benefit of the advisory services (Singh et al., 2020; Das et

Table 4: Cost of cultivation of capsicum incurred to AAS and Non-AAS farmers in five blocks of Solan district

Operations/ Quantity		Saving or loss (%)											
		AAS farmers						Non-AAS farmers					
		B_1*	B_2	B_3	B_4	B_5	Mean	B_1	B_2	B_3	B_4	B_5	Mean
Input	a) Field	7.0	6.3	18.7	6.2	4.0	8.4	-6.5	-5.9	-15.8	-5.8	-3.8	-7.6
	b) Seed	0.3	0.0	0.0	0.0	0.0	0.1	-0.3	0.0	0.0	0.0	0.0	-0.1
	c) Manure	6.5	9.9	11.2	7.8	12.3	9.5	-6.1	-9.0	-10.0	-7.2	-11.0	-8.7
	d) Pesticide	6.2	2.2	6.6	8.5	7.3	6.2	-5.9	-2.2	-6.2	-7.8	-6.8	-5.8
	e) Irrigation	23.4	2.8	-6.1	9.9	2.1	6.4	-18.9	-2.8	6.5	-9.0	-2.0	-5.2
	f) Labour	4.3	2.8	22.5	7.3	23.8	12.1	-4.1	-2.7	-18.4	-6.8	-19.2	-10.2
	g) Harvesting	16.8	2.6	4.0	6.7	3.9	6.8	-14.4	-2.5	-3.8	-6.3	-3.8	-6.2
Total (a-g)	6.8	6.8	8.0	3.4	8.6	6.3	6.7	7.2	-7.4	-3.3	-7.9	-5.9	-6.2
Output	Yield (q ha^{-1})	4.5	4.5	3.4	2.4	2.3	3.4	-4.7	-4.7	-3.6	-2.4	-2.4	-3.6
	Gross return	4.4	4.5	3.4	1.1	2.3	3.1	-4.6	-4.7	-3.6	-1.1	-2.4	-3.3
	Net profit	10.9	9.4	11.3	10.3	9.5	10.3	-12.2	-10.4	-12.8	-11.5	-10.5	-11.5

*B_1: Solan; B_2: Kandaghat; B_3: Dharampur; B_4: Kunihar; B_5: Nalagarh

al., 2018) mentioned that differences in cost of cultivation might be due to differences in expenditure on fertilizer and pesticides as well as wages for human labour. The reduction in labour and irrigation cost among AAS farmers reflects improved decision-making based on medium-range weather forecasts. Similar improvements in input-use efficiency and profitability due to adoption of agromet advisories have been reported by recent studies (Pradhan et al., 2023; Kaur et al., 2024; Singh et al., 2020).

3.3. Cauliflower

For the cultivation of cauliflower the percent saving of different inputs incurred to the AAS farmers and losses to the Non-AAS farmers were given in Table 5. The maximum saving was observed for irrigation (45.5%) in Dharampur block (B_3) followed by seed (17.8%) in Solan block (B_1) and the minimum was for labour (3.5%) in Solan block followed by manure (3.8%) in Kandaghat block (Table 5). The non-AAS farmers were incurred highest extra cost in term irrigation (31.3%) in Dharampur followed by Solan block (15.1%) for seed and for labour (13.9%) in Kunihar block which indicated the impact of agromet advisories in scheduling of various input applications. In total 7.2% extra cost was incurred to the non-AAS cauliflower grower in the district. In the cauliflower cultivation, on an average the AAS farmers were able to save 7.8% of inputs costs and gained 9.8% net profit whereas non-AAS farmers was incurred with 7.2% higher input cost with net loss of 10.8% (Figure 5). This indicated a clear impact of agromet advisories on the cauliflower crop economy to the growers. The benefit derived from the results also showed that the AAS category had a better net income and lower cost of production, which were also due to the judicious use of farm inputs based on the real time agrometeorological advisories (Pradhan et al., 2023). Similar results were obtained by (Maini and Rathore, 2011) which showed that AAS farmers accrued a net benefit of 10–15% in the overall yield and a reduction by 2–5% in the cost of cultivation over the non-AAS farmers. These findings are in close agreement with recent impact assessment studies which reported 8–12% higher net returns and significant savings in irrigation and plant protection cost due to weather-based advisories (Kaur et al., 2024; Kumar et al., 2021).

Table 5: Cost of cultivation of cauliflower incurred to AAS and Non-AAS farmers in five blocks of Solan district

Operations/ Quantity		Saving or loss (%)											
		AAS farmers						Non-AAS farmers					
		B_1^*	B_2	B_3	B_4	B_5	Mean	B_1	B_2	B_3	B_4	B_5	Mean
Input	a) Field	5.0	9.9	10.0	7.2	6.2	7.7	-4.7	-9.0	-9.1	-6.7	-5.8	-7.1
	b) Seed	17.8	0.0	0.0	0.0	0.0	3.6	-15.1	0.0	0.0	0.0	0.0	-3.0
	c) Manure	14.6	3.8	11.5	9.8	13.7	10.7	-12.7	-3.6	-10.3	-8.9	-12.1	-9.5
	d) Pesticide	7.7	6.7	5.6	11.4	7.6	7.8	-7.2	-6.3	-5.3	-10.2	-7.1	-7.2
	e) Irrigation	10.0	8.4	45.5	14.5	8.9	17.5	-9.1	-7.8	-31.3	-12.6	-8.2	-13.8
	f) Labour	3.5	9.0	16.9	16.1	4.5	10.0	-3.4	-8.3	-14.5	-13.9	-4.3	-8.9
	g) Harvesting	5.9	8.6	3.9	6.8	9.8	7.0	-5.6	-7.9	-3.7	-6.4	-8.9	-6.5
Total (a-g)		6.8	7.8	7.0	7.6	8.8	7.8	-7.2	-6.5	-7.0	-8.1	-7.2	-7.2
Output	Yield (q ha^{-1})	2.3	3.4	3.0	2.6	2.1	2.7	-2.3	-3.5	-3.1	-2.7	-2.2	-2.8
	Gross return	2.3	3.4	3.0	1.2	1.2	2.2	-2.3	-3.5	-3.1	-1.2	-1.2	-2.3
	Net profit	9.3	9.3	10.0	10.7	9.5	9.8	-10.2	-10.3	-11.1	-12.0	-10.5	-10.8

*B_1: Solan; B_2: Kandaghat; B_3: Dharampur; B_4: Kunihar; B_5: Nalagarh

3.4. Pea

For the cultivation of pea the percent saving of different inputs incurred to the AAS farmers and losses to the Non-AAS farmers were given in Table 6.

The maximum saving was observed for irrigation (46.8 %) in Dharampur block (B_3) followed by (30.1%) in Nalagarh block (B_5) and the minimum was for labour (1.2%) in Kandaghat block followed by harvesting (1.4%). The cost of seed was at par with the Non-AAS farmers in B_1, B_2, B_3 and B_4 but observed (11.1%) saving in B_5 (Table 6).

The non-AAS farmers were incurred highest extra cost in term irrigation (31.9%) in Dharampur block followed by Nalagarh block (23.1%) and for field preparation (19.2%) in Solan block which indicated the impact of agromet advisories in scheduling of irrigation and other input applications. In total 6.2% extra cost was incurred to the non-AAS pea grower in the district. In the pea cultivation, on an average the AAS farmers were able to save 6.7 % of

Table 6: Cost of cultivation of pea incurred to AAS and Non-AAS farmers in five blocks of Solan district

Operations/ Quantity		Saving or loss (%)											
		AAS farmers						Non-AAS farmers					
		B_1*	B_2	B_3	B_4	B_5	Mean	B_1	B_2	B_3	B_4	B_5	Mean
Input	a) Field	23.7	3.8	18.9	6.0	11.6	12.8	-19.2	-3.7	-15.9	-5.6	-10.4	-11.0
	b) Seed	0.0	0.0	0.0	0.0	11.1	2.2	0.0	0.0	0.0	0.0	-10.0	-2.0
	c) Manure	10.3	4.8	9.5	5.9	9.7	8.0	-9.3	-4.5	-8.7	-5.5	-8.9	-7.4
	d) Pesticide	7.5	2.3	5.7	7.1	9.5	6.4	-7.0	-2.2	-5.4	-6.6	-8.7	-6.0
	e) Irrigation	18.1	3.3	46.8	23.6	30.1	24.4	-15.3	-3.2	-31.9	-19.1	-23.1	-18.5
	f) Labour	23.4	1.2	14.3	6.5	16.0	12.3	-18.9	-1.2	-12.5	-6.1	-13.8	-10.5
	g) Harvesting	5.2	1.4	2.3	2.8	3.6	3.1	-5.0	-1.4	-2.2	-2.7	-3.5	-3.0
Total (a-g)		6.8	9.7	2.2	7.4	5.1	6.7	9.1	-8.9	-2.1	-6.9	-4.8	-6.2
Output	Yield (q ha^{-1})	2.0	5.3	2.7	3.0	2.0	3.0	-2.0	-5.6	-2.8	-3.1	-2.0	-3.1
	Gross return	2.0	5.3	2.7	3.0	2.0	3.0	-2.0	-5.6	-2.8	-3.1	-2.0	-3.1
	Net profit	8.8	9.1	8.9	7.7	9.8	8.9	-9.7	-10.0	-9.8	-8.3	-10.9	-9.7

*B_1: Solan; B_2: Kandaghat; B_3: Dharampur; B_4: Kunihar; B_5: Nalagarh

inputs costs and gained 8.9% net profit whereas non-AAS farmers was incurred with 6.2% higher input cost with net loss of 9.7% (Figure 5). This indicated a clear impact of agromet advisories on the pea crop economy to the growers. Hence, we couldsay that agro-advisory services showed positive results in terms of yield, production and net income. Similar results were obtained by (Kaur et al., 2024; Darbyshire et al., 2020), where net profit for AAS farmers was ₹ 23479 acre^{-1} and under non-adopted AAS it was ₹ 19383. Further, better crop management practices based on advisories such as timely sowing, selection of improved crop cultivar, timely application of fertilizer, pest and disease management, lifesaving irrigation and harvesting which helped them to reduce the cost of production over non-AAS farmers (Singh et al., 2022). The economic advantage of AAS farmers was mainly attributed to timely sowing, life-saving irrigation and efficient pest management based on forecast information. Similar results have been reported in recent studies for different crops under diverse agroclimatic conditions (Kaur et al., 2024; Singh et al., 2022; Darbyshire et al., 2020).

4. CONCLUSION

The highest usable forecast for rainfall, T-max and for RH_e was 95.4%, 76% and 62.7%, respectively during post-monsoon but for RH_m in monsoon (97.8%). The timely and accurate weather information based agromet advisories helped farmers in rescheduling their agricultural activities, ultimately leading to improved profitability. Farmers who utilized these weather-based advisories have reduced the cost of cultivation by 6% to 8% and hence, incurred 8–11% higher net economic return compared to non-AAS vegetables growers in the study area.

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