Economic impact assessment of the Agrometeorological Advisory Service of India

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A pilot study was conducted to assess the economic impact of weather forecast-based advisories issued to 15 of the 127 Agrometeorological Advisory Service (AAS) units of the Ministry of Earth Sciences, Government of India. Six seasons comprising three Kharif (summer) and three Rabi (winter) during 2003–2007 were chosen. The major crops chosen for the study included food grains, oilseeds, cash crops, fruit and vegetable crops. The sample set consisted of 80 farmers, comprising 40 responding and 40 non-responding farmers. The main aim was to study the percentage increase/decrease in the yield and net return due to AAS. Results obtained suggest that the 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.

Keywords: Advisories, Agrometeorology Advisory Service, economic impact, yield.

AGRICULTURAL productivity largely depends upon weather. Weather forecasts in all temporal ranges are desirable for effective planning and management of agricultural practices. The development of response strategy[1] helped farmers realize the potential benefits of using weather-based agrometeorological information in minimizing the losses due to adverse weather conditions, thereby improving yield, quantity and quality of agricultural productions. In fact, short and medium-range weather forecasts play a significant role in making short-term adjustments in daily agricultural operations.

Some of the early works that appeared in the late 1960s concentrated on effectiveness of agrometeorological information[2–4]. Studies have also been carried out to determine the potential benefits in agricultural farm decisions from long-range weather predictions[5–9], in particular in areas where the El Niño/Southern Oscillation has marked impact on the regional climate[10,11]. However, very little work has been done on the economic impact of medium-range weather forecasts on farm-level decisions. In general, it is difficult to assess the economic benefit of any advisory service given to take measures against catastrophes or life-threatening situations, but it is possible to assess the economic benefit of the agrometeorological services[12]. This can be done if the scientific methods to be used for weather-based advisories have a direct relationship with the traditional knowledge of the farmers[11]. From a farmer's perspective, the forecast value increases if the weather and climate forecasts are capable of influencing their decisions on key farm management operations[13–15]. Thus, it becomes essential to relate with the requirements of farmers[16], understand their needs and give the forecast in appropriate spatial and temporal range[17–20]. This ultimately helps in increasing the reliability of the forecast and thus in better adoption of the weather-based advisory[21].

The National Centre for Medium Range Weather Forecasting (NCMRWF) under the Ministry of Earth Sciences (MoES), Government of India in collaboration with India Meteorological Department (IMD), Indian Council of Agricultural Research and State Agricultural Universities had been providing Agrometeorological Advisory Services (AAS) at the scale of agroclimatic zone to the farming community based on location-specific medium-range weather forecast (MRWF)[22]. Since 2007, the entire framework of AAS, developed and successfully demonstrated by NCMRWF, has been relocated at IMD under MoES for extending the service (in operational mode) to districts under these agro-climatic zones. It is now called the Integrated Agrometeorological Advisory Service of MoES. Thus, the AAS set up exhibits a multi-institutional, multidisciplinary synergy to render an operational service for use of the farming community.

These weather-based agro-advisories have been helping the farming community to take advantage of prognosticated weather conditions and thereby form a response strategy. This was also reported by the AAS units. But these were sporadic cases and could not be intercompared mainly due to non-uniform use of the methodology. Hence, a detailed study was carried out at 15 AAS units

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with an objective to evaluate the use and value of the service in economic terms. This also helped in assessing the usage pattern of AAS and identifying the strengths and weaknesses of the service. The impact studies have indicated that the weather based advisories issued by NCMRWF had a positive impact on the overall yield and also helped in decreasing the cost of cultivation. One of the major achievements of the study was that it helped in increasing awareness among farmers about the adoption of weather based advisories and their positive impacts. The present article discusses the pilot study, its methodology and impact of AAS.

Preparation, dissemination and feedback mechanism of the agro-advisory bulletin

For issuing the weather based agro-advisories, a forecasting system for generating[23] objective medium-range location-specific forecast of surface weather elements has been evolved at NCMRWF[24–26]. Location-specific weather forecasts for six parameters, viz. rainfall, cloud cover, wind direction and speed, and minimum and maximum temperature were obtained twice a week from a T-80 General Circulation Model with a resolution of 150 km × 150 km. These forecasts were further subjected to statistical[27,28] and synoptic interpretation by experts and 5-days forecasts in quantitative terms were issued to the AAS units twice a week. These forecasts were converted into farm-level advisories by AAS units and disseminated to the farmers in vernacular language through mass media[22]. Public awareness programmes in 'kisan melas' are regularly held by agricultural universities to educate farmers on the usage of farm advisories. Figure 1 shows the complete flow diagram of the AAS of NCMRWF.

In order to regularly assess the quality and skill of forecast, a verification mechanism was introduced[24–31], wherein verification was done by the service provider (NCMRWF) as well as the user community (farmers). Here the verification is presented during two main cropping seasons, namely Kharif and Rabi for all the 15 units during the period of study. The evaluation of usability of forecast of quantitative precipitation and temperature (maximum (T_x); minimum (T_n)) was done using an error structure formulated at NCMRWF[25,26] and is given in Table 1. Table 2 give the skill in terms of ratio score (RS) and Hanssen and Kuipers Score (HKS) for rainfall forecast and correlation coefficient (CC) and root mean square error (RMSE) for temperature forecast during the period of study. Although the skill of forecast follows a similar trend every year[32–34], a distinct difference is seen in the Kharif and Rabi seasons.

It is observed from Table 2 that the RS of Yes/No rainfall forecast is around 90% during Rabi and 69% in Kharif. Similarly on an average the HKS is around 0.4 during Kharif and 0.5 during Rabi. T_x has a correlation of 65–70% and an RMSE of 2–3°C in Kharif, whereas in Rabi the correlation is around 60%. On the other hand, the correlation of T_n forecast is around 50% in Kharif and about 65% in Rabi season. The RMSE of T_n is lower than that of T_x and is in the range 1–2.5°C during both seasons.

The usability of the temperature and rainfall forecast is given in Table 3. While in the case of quantitative precipitation, the Rabi forecast (90–98%) is better than the Kharif forecast (60–80%), in temperature forecast it is observed that the usability is good during both seasons, with maximum temperature having higher usability in Rabi (50–90%) and minimum temperature in Kharif (60–95%).

AAS units also reported periodic feedback on worthiness of forecasts and usefulness of advisories in economic terms. Although these studies gave an initial idea about the value of forecast, tangible conclusion could be arrived at only by carrying out the study in greater detail.

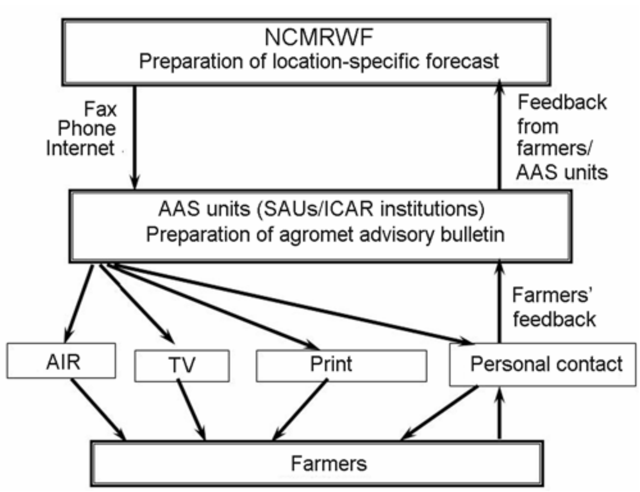

Figure 1. Agrometeorological Advisory Service (AAS) of the National Centre for Medium Range Weather Forecasting (NCMRWF).

Table 1. Criteria for obtaining usability of quantitative precipitation and temperature forecast

	Observed rainfall ≤10 mm	Observed rainfall >10 mm
Correct	Diff ≤ 0.2 mm	Diff ≤ 2% of obs
Usable	0.2 mm < Diff ≤ 2.0 mm	2% of obs < Diff ≤ 20% of obs
Unusable	Diff >2.0 mm	Diff > 20% of obs

Diff, Absolute difference of rainfall observed and forecast (in mm).
Obs, Observed rainfall (in mm).

Correct	Diff ≤ 1°C
Usable	1°C < Diff ≤ 2°C
Unusable	Diff > 2°C

Diff, Absolute difference of temperature observed and forecast (in °C).

Table 2. Skill of forecast during the study period

	Kharif						Rabi					
	Rain		T_n		T_x		Rain		T_n		T_x	
Station	RS	HKS	RMSE	CC	RMSE	CC	RS	HKS	RMSE	CC	RMSE	CC
Anand	74	0.45	1.59	0.68	1.97	0.87	92	0.37	2.35	0.69	1.54	0.8
Bangalore	57	0.19	1.29	0.17	1.68	0.7	84	0.25	1.94	0.64	1.64	0.37
Bhubaneshwar	65	0.3	1.65	0.54	2.7	0.74	98	0.41	2.35	0.32	1.93	0.41
Hisar	75	0.38	2.61	0.55	2.7	0.6	96	0.3	2.12	0.68	2.85	0.7
Coimbatore	60	0.13	1.67	0.29	2.33	0.33	87	0.42	1.89	0.58	1.89	0.61
Hyderabad	56	0.24	1.53	0.64	2.54	0.81	95	0.39	1.98	0.74	1.5	0.66
Jaipur	62	0.25	2.49	0.51	3.13	0.6	91	0.22	2.99	0.67	2.07	0.76
Jodhpur	80	0.48	2.78	0.45	2.97	0.65	96	0.32	2.34	0.69	1.68	0.74
Ludhiana	70	0.31	2.61	0.6	3.69	0.53	87	0.38	2.86	0.62	2.41	0.68
Nadia	78	0.33	1.6	0.28	2.24	0.35	93	0.74	2.4	0.61	2.64	0.51
Pantnagar	72	0.56	1.85	0.39	2.63	0.77	92	0.46	2.14	0.77	3.09	0.31
Pune	67	0.2	1.21	0.54	1.88	0.54	98	0.5	2.67	0.53	2.45	0.56
Raipur	67	0.33	1.79	0.58	2.36	0.81	94	0.41	2.43	0.52	2.5	0.6
Solan	70	0.42	1.87	0.56	2.23	0.82	87	0.56	2.13	0.77	2.86	0.69
Thrissur	82	0.5	1.22	0.2	1.66	0.6	89	0.22	1.31	0.62	1.76	0.22

RS, Ratio score; HKS, Hanssen and Kuipers score; RMSE, Root mean square error and CC, Correlation coefficient.

Table 3. Usability (in %) of rainfall and temperature forecast during the study period

	Kharif			Rabi		
Station	Rain	T_n	T_x	Rain	T_n	T_x
Anand	66.78	82.84	70.89	99.23	68.48	89.34
Bangalore	68.02	97.61	77.28	98.66	74.67	88.57
Bhubaneshwar	54.34	89.07	58.58	98.65	56.58	71.25
Hisar	88.89	70.73	65.61	95.77	56.33	58.62
Coimbatore	85.88	82.68	75.21	95.95	72.73	85.19
Hyderabad	55.87	89.71	70.33	96.11	90.00	87.30
Jaipur	82.67	71.31	57.37	100.00	62.07	67.81
Jodhpur	75.89	75.23	60.33	100.00	65.49	71.33
Ludhiana	84.57	61.51	59.84	90.00	59.77	64.37
Nadia	65.43	84.03	63.73	100.00	53.33	65.34
Pantnagar	57.17	56.94	40.27	94.59	56.25	43.75
Pune	61.35	90.59	75.13	100.00	66.24	87.50
Raipur	67.44	77.20	65.99	96.34	65.52	79.31
Solan	60.25	78.78	64.94	96.92	65.38	60.26
Thrissur	66.44	95.84	87.50	100.00	90.25	82.98

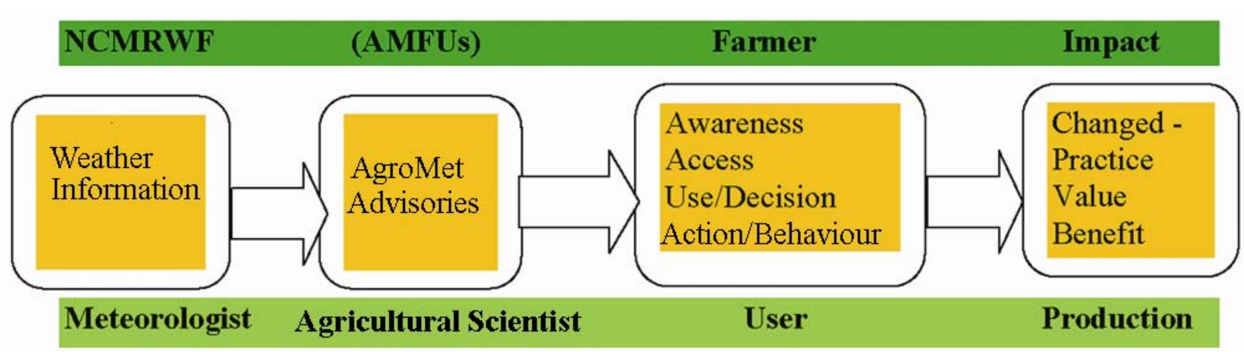

Figure 2. Schematic diagram showing the steps involved in the assessment of the impact of AAS.

Impact assessment of AAS

Agromet impact study paradigm

There does not exist any general simulation model for the evaluation of the economic benefits of meteorological assistance to agriculture. However, the benefit can always be assessed in terms of what is apparent or possible and what can be the maximum possible benefit theoretically.

The schematic diagram in Figure 2 depicts the various stages of the study. As a first step, quantitative weather forecast generated at NCMRWF was disseminated to Agro Meteorological Field Units (AMFU) in quantitative terms along with information of adverse weather, if any. Weather information was then translated into farm level action-oriented advice by the agricultural scientists at AMFU. It contained weather based advisories, including time and method of sowing, time and amount of irrigation, time and method of fertilizer/pesticide application, etc. Agriculture impacts realized included changes experienced by farmers in terms of a positive (a benefit effect) or negative (an undesired effect) effect, thereby helping them to decide on the selection of crop/variety, sowing/harvesting time, irrigation management, fertilizer management, pest/disease management and other intercultural operations. This formed the backbone of the economic impact study carried out by NCMRWF in collaboration with AAS units.

Preliminary outline

Once the outreach of AAS and skill of the forecast were established, it was pertinent to study the impact of the service in terms of economic gain/loss. Although some of AAS units reported the benefits accrued by the farmers, they were generally qualitative. This helped in creating a modest awareness about the impact of the weather-based agro-advisories on the farming sector, but there was lack of a clear and precise understanding of the impact. Therefore, there was a need to carry out an impact assessment study using specified impact criteria and with a uniform pattern of study.

Assessing impacts of weather forecast application in farm management sector is a stupendous task. It becomes even more challenging if one is attempting to quantify the value of weather forecast-based agro-advisories. It was difficult to consider all crop and all agro-climatic situations. Hence a conscious decision was taken to undertake the study at 15 representation sites (Figure 3) covering principal crops (cereal, millets, fruits and vegetables, oilseeds and cash crops). The study period was spread over 3 years, comprising three Kharif (2004, 2005 and 2006) and three Rabi seasons (2004–05, 2005–06 and 2006–07). The National Centre for Agriculture Economics and Policy Research (NCAP), which was engaged as a consultant for the project, helped formulate the study plan, including devising the sampling method, preparation of the questionnaire and monitoring its implementation. NCMRWF on its part was responsible for conceptualizing and executing the study, providing grants and bringing out the final report.

Benefits or expectations from these studies

It was envisaged that the project

- Will give an insight into forecasting skill and reach of the service and also its economic value in terms of money.
- Will help in conducting farm operation in tune with weather forecasts leading to energy-saving, enhancing the efficacy of inputs such as fertilizer, pesticide, etc., cutting the cost of cultivation and saving crop from adverse weather.
- Will help in assessing the impact of favourable weather on overall growth, development and final yield of the crop.
- Will give agromet advisories that will increase profits by consistently delivering actionable weather information, analysis and decision support for farming situations such as pest management through forecast of relative humidity, temperature and wind; water management through rainfall forecasts and crop protection from thermal stress through forecast of extreme temperature conditions.

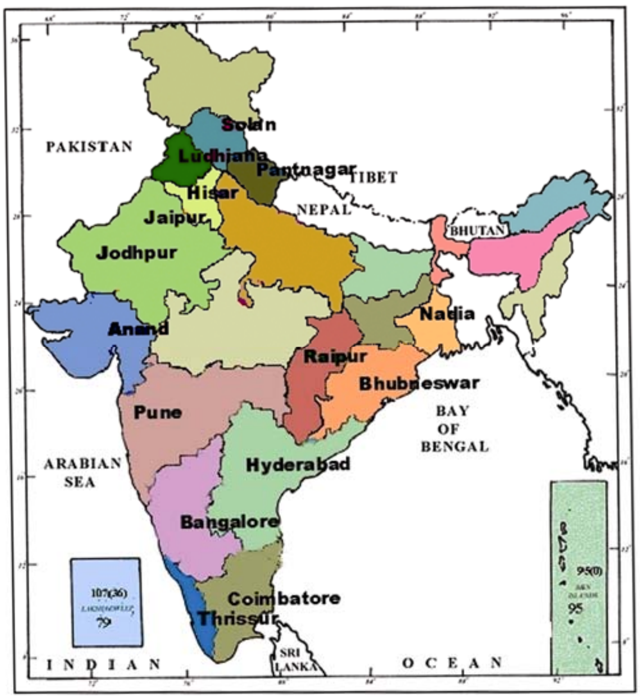

Figure 3. Network of stations chosen for the study.

Hence it was expected that through intelligent use of weather-based farm advisories, the study would facilitate protection of natural resources and preservation of the environment.

Objectives of the study

- To study the adoption of the forecast by the user community and its realization, thus understanding the linkages between information, users and impacts.
- To assess the use, effectiveness and potential benefits of AAS by taking into account the AAS contact and non-contact farmers.
- To understand and formulate weather-based farming strategies based on the economic impact of AAS.
- To recognize the needs of the farming community for increasing the farm produce.
- To assess the economic impact of AAS in various crops under different agro-climatic conditions.

It also included other components of AAS such as dissemination of the bulletins, outreach of the service, and capacity of the user community in adopting the advisories by different sections of the society under varying education, gender and socio-economic classes. The impact assessment framework also encompassed the aspects related to skill of weather forecast[35], its reliability and adequacy, mechanism of flow of weather information, and extent of use of weather-based advisories by farmers for economic gains. It however did not cover the evaluation of the capacity and methods of weather forecasts, which were beyond the scope of the present study.

Impact assessment analysis framework

The selection of the analytical method is determined by the objective of the study, availability of required data and computational skills. Since the main objective of the study was to assess the adequacy, use and impact of the medium-range weather forecasts, an analytical method focusing more on farm-level impact was considered to be the most appropriate. Therefore, NCAP proposed the use of simple farm-level indicators for the impact assessment. The impact assessment framework included estimation of accuracy of the forecast, adequacy and reliability of the forecast from the farmers' perspective, use of the forecast and farm-level impacts.

Table 4 describes the framework followed for assessing the usefulness of weather forecast through the survey and Table 5 gives the economic impact indicators considered.

Sample selection

Considering the importance of sampling in the study, care was taken to identify the sample which is the true representative of the class. Thus farmers were selected based on their size of holding (small, medium, large), educational background, size of the family and type of crop grown. The next section gives the demographic details of the samples chosen by each unit.

Out of a total of 127 AAS units, 15 were selected based on the existence of an effective weather-based AAS at the unit for a few years. From each unit, a representative district where AAS unit was operating was selected for conducting the farm survey. The selection of the district was based on its similarity with the agro-climatic zone in terms of cropping pattern, irrigated area, and rainfall and soil type. A list of villages, from the selected district, having AAS contact farmers was prepared and two villages were chosen randomly from among these. From each selected village, a list of all AAS contact farmers was prepared by category of their size of holding (small, medium, large), educational background, family size,

Table 4. Use of weather forecasts

Impact area	Indicator
Perception of stakeholders	Reliability, dissemination, adequacy, value-addition
Awareness about AAS	Farmers knowing about AAS (%)
Usefulness – perception of farmers	Farmers considering it useful (%)
Use of information	Farmers using weather forecasts (%)

Table 5. Economic impact indicators

Parameter	Indicator
Yield	Difference in yield of AAS and non-AAS farmers.
Cost	• Difference between total paid out cost (per acre) of AAS and non-AAS contact farmers. • Changes in cost per unit of output.
Profitability	Difference in return over paid out cost (Rs/acre) of AAS and non-AAS contact farmers.
Utility	Increase in utilization by farmer for manoeuvring cultural operations.

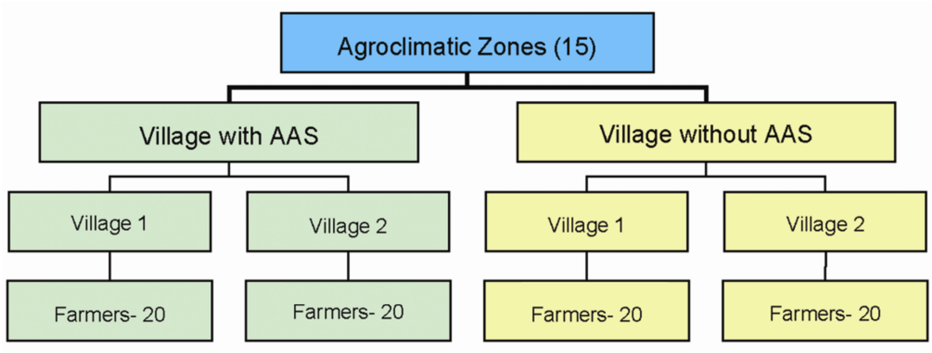

Figure 4. Schematic diagram showing the sampling framework.

type of crop grown, etc. A total of 20 farmers were then selected using random sampling technique. Thus a sample size of 40 AAS contact farmers was selected from two villages. Similarly, the non-AAS farmers were chosen. Thus a sample of 80 farmers (40 AAS and 40 non-AAS) was chosen for the study as shown in Figure 4. Due to certain constraints, at times the Nodal Officers carried out the study with fewer farmers.

Survey and the questionnaire

The sampling method was designed to work directly with the users of forecast and advisory information, and to meaningfully assess credible cost/loss estimates. The important issue was to develop an effective and meaningful base for assessing the impacts of cost-cutting yield and enhancing decisions. Cost-cutting measures can take a variety of forms, some of which include saving in irrigation, reducing the loss of fertilizer, reducing pesticide application, etc. To obtain quantitative information, working relationships between AMFUs and user farmers were set up through periodic visits. Through such visits, inputs from the farmers were obtained about use and application of the advisory bulletins through a pre-devised questionnaire. Thus the sample survey was not independently conducted by the agency which provided the questionnaire and therefore, a certain amount of bias was inevitable. This is one of the limitations that has been encountered during the study.

The survey gave special attention to dates of sowing, planting, harvesting, spraying, irrigation and tillage operation. Emphasis was given on collecting information on the adoption of advisory by the farmers during such operations and the benefit/loss accrued by them on following/not-following the advisories related to such crucial operations.

Based on the above methodology and impact assessment framework, the survey was done using three aspects.

- Socio-economic status: The socio-economic status of the farmers was surveyed using queries related to the following in the questionnaire: (a) family structure; (b) literacy among farmers; (c) size of land holding; (d) cropping pattern; (e) traditional methods used; (f) awareness of AAS; (g) mode of receipt of AAS; (h) weather parameters required; (i) satisfaction from service (reliability, timely availability, expected benefits, frequency) and (j) willingness to pay. Results from a few are given in the next section.
- Quantity analysis of inputs used: (a) quantity of seed, fertilizer, pesticide; (b) number of labour (human, machine) and (c) number of irrigations.
- Price analysis of inputs used: (a) price of seed, fertilizer, pesticide; (b) cost of labour (human, machine); (c) cost of irrigation; (d) cost of product/by-product and (e) any other associated cost.

The major crops chosen for the study were: food grains (wheat, rice, millets, maize, red gram and chickpea); oilseeds (mustard); cash crops (cumin, jute, cotton and tobacco); fruit crops (apricot, peach and banana) and vegetables (tomato and spinach).

Survey results of socio-economic features of farmers

For the purpose of comparison of the socio-economic features of households, the 15 chosen units were divided into four zones: North (Ludhiana, Hisar, Pantnagar, Solan); West (Jaipur, Jodhpur, Anand, Pune); East (Raipur, Nadia, Bhubaneshwar) and South (Bangalore, Hyderabad, Coimbatore, Thrissur).

Family structure of farmers

The family structure in most cases was 3–7 members per family. Educated and prosperous farmers had smaller family size when compared to their counterparts. The pie chart shown in Figure 5 depicts the age group of farmers in different zones of India. It is seen that in the South, more than 70% of the farmers are in the age group of 35

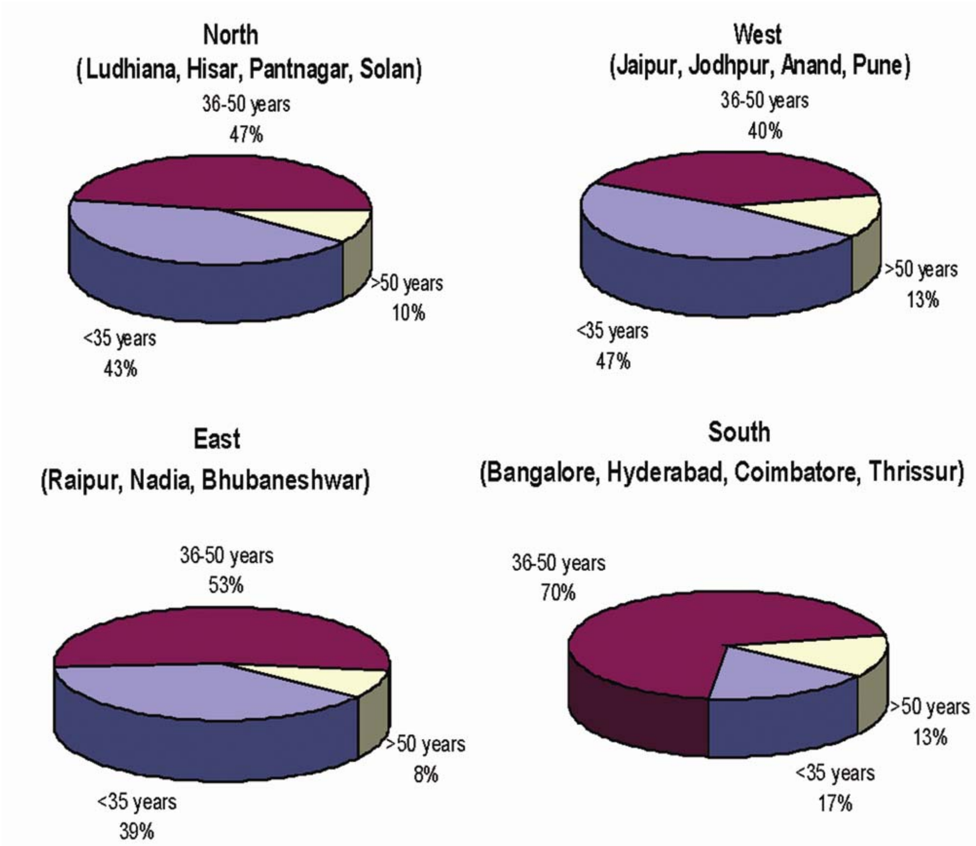

Figure 5. Pie chart depicting the age group of farmers in different zones of the country.

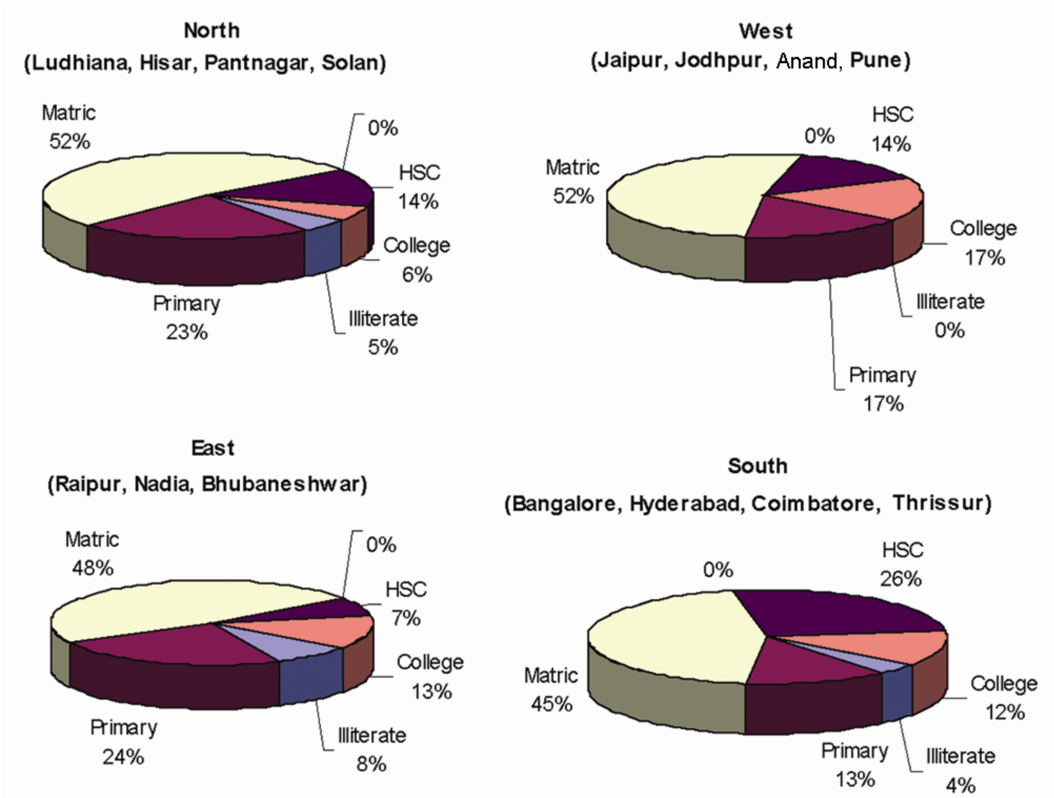

Figure 6. Pie chart depicting the educational level of farmers in different zones of the country.

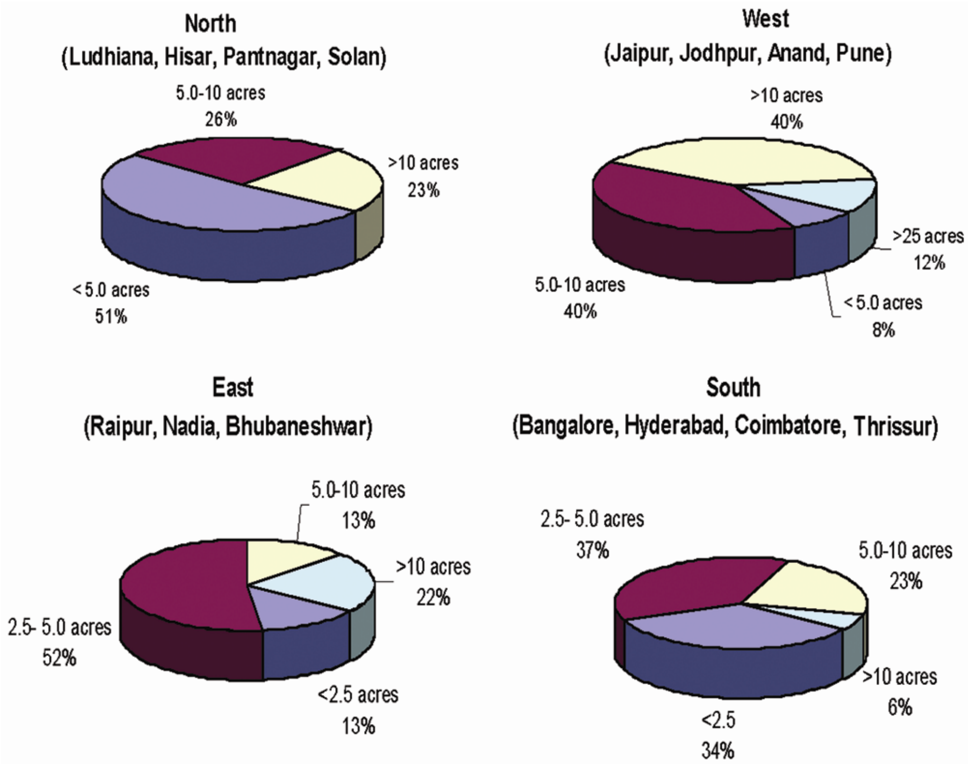

Figure 7. Pie chart showing the land holdings owned by different farmers of the country.

or more (83%); followed by the East (61%) and North (57%). In the West 47% of the farmers are less than 35 years of age. On the average most of the farmers belong to the middle-level age group. This implies that the younger generation may not be interested to take up farming as a profession.

Literacy among farmers

Figure 6 shows the education level of farmers in the four zones of the country. It shows that 52% of the farmers in the North and West are at least matriculate followed by the East (48%) and South (45%). Although the percentage of illiterate farmers is less (about 0–8), it is highest in the East and nil in the West. Interestingly, about 6–17% of the farmers are college pass with the West, thus leading in this category.

Size of land holding

Figure 7 depicts the size of land holdings of the farmers in the four zones. In general, farmers in the West have large land holdings, with 12% of them having land holdings greater than 25 acres, followed by 40% in the 10–25 acre category. This is followed by stations in the North where 23% farmers have land holdings greater than 10 acres; 26% have land holdings in the 5–10 acre category and the rest 51% have less than 5 acres. In the East and South zones, the farmers generally have small to medium land holdings ranging between 2.5 and 5 acres (East – 65%; South – 71%). About 22% of the farmers in the East and 6% in the South have land holdings greater than 10 acres.

Sources of weather forecast

AAS farmers received weather bulletins from different sources, viz. radio, television, newspaper; AAS bulletin in printed form/public notice, or through telephone/fax/ personal contact with AAS. Among these, radio and television remained the most popular and easily accessible media through which 60–70% farmers could get information on weather forecast. Literate farmers comprising about 20% could read the detailed weather-based agro-advisory bulletin in newspapers and take corrective action. On several occasions, they contacted agricultural extension workers and took their advice for various operations.

Frequency and reliability of forecast

It was concluded from the study that almost 90% of the farmers gave more importance to forecast of rainfall and temperature over wind speed, wind direction and cloud cover. Wind speed and direction and cloud cover play an important role during infestation of pest and disease. About 60–80% of the AAS farmers were keen to have weekly cumulative rainfall forecast for carrying out their various farm operations. About 20% of the AAS farmers were interested to obtain the seasonal forecast of rainfall in order to plan their sowing and harvesting operations in advance. Almost all AAS farmers opined that the weather bulletin was received by them on time and 60–70% felt that the rainfall forecast and the temperature trends were reliable. A large group of 70–80% farmers felt that the forecast of wind direction was bad.

Willingness to pay for the service

The credibility and worthiness of a service is realized by its acceptability in totality and the readiness on the part of the user to pay for the service. In the 10–15 years of its existence, AAS had established sufficient credibility and reliability among the farming community. As a result, the farmers implemented the free advice given through the service and also accrued substantial benefits. So it was pertinent to assess through this survey the willingness of the farmers to pay for the service. Therefore, a specific question about the farmers 'willingness to pay' was also included in the survey. Though the reply to this particular question was neither forthcoming nor overwhelming, it definitely helped in analysing the effectiveness and worthiness of weather forecast and also the risk-taking ability of the sample farmers. The situation under which a farmer was ready to pay included: (a) expected weather-induced losses, (b) risk-taking ability of a farmer (income and assets) and (c) reliability of forecast.

Though most of the AAS farmers were not ready to pay and were willing to implement the weather-based advisories free of cost, there was a small group of farmers in Jaipur, Hyderabad and Pune, who were willing to pay for the service. This group possesses medium to large land holdings. They generally cultivate cash crops and are ready to pay for the service if the price is nominal and the service is specific to their needs. Farmers with small land holding are unwilling to pay as they are generally poor and take huge loans against their holdings and so do not possess the risk-taking ability.

Survey results of quantity and price analysis

Using the questionnaire designed by NCAP, the Nodal Officer carried out the survey at specified time schedules that coincided with different operations like land preparation, sowing, planting, irrigation scheduling, fertilizer applications, harvesting and post-harvesting operations. The survey included questions on date of operation, the action taken by the farmer in view of the impending weather/advisory, cost of seed, labour applied in terms of both machine and human, number of irrigations undertaken, fertilizers applied, harvest technology adopted and various other issues. The data collected were eventually used to assess the impact of AAS in economic terms. The direct impact of AAS on the cost of cultivation, gross net returns and impact on yield was an important part of the economic analysis. The overall analysis in terms of percentage of increase in yield and total input cost was calculated for each of the crops considered[36]. For convenience of the present study, results from two representative stations are presented for each category of crops, viz. cereal, millets, oilseeds, cash crops, pulses, fruits and vegetables.

Table 6 gives the cost of cultivation (Rs/acre), gross returns (Rs/acre) and B : C (benefit to cost) ratio for both AAS and non-AAS farmers during the Kharif and Rabi seasons in all three years. The B : C ratio is higher for the AAS farmers compared to the non-AAS farmers, though for certain crops the difference is less. Least variation in the B : C ratio is seen for the cereal crops grown in the northern belt of India (Ludhiana, Pantnagar, Hisar, etc.). This may be attributed to the large land holdings of the farmers who have access to assured irrigation in this part of the country. In general, the vegetable and fruit crops have higher B : C ratio. This is because these crops are highly weather-sensitive and a slight deviation of forecast from that realized can have tremendous impact on the overall yield. In fact, the cost of cultivation is higher in Rabi 2004–05 for all vegetables. This may be attributed to the use of more fertilizers, irrigation and pesticides. The cash crops like cotton, jute and tobacco are generally taken up by farmers who have high risk-taking capability. As a result, in addition to their own experience, they follow the weather advisories carefully and thus save on the overall loss to the crop. Thus not much variation is seen in AAS and non-AAS farmers, except in the case of jute crop taken up by Kalyani farmers. The AAS farmers who grow Rabi crops like wheat, gram and mustard in North India show higher B : C score compared to crops grown during Kharif. This again establishes the fact that the overall skill of the NWP models is higher during the winter season.

In order to statistically test if the yield of the AAS farmers is significantly higher when compared to the non-AAS farmers, we applied the unpaired *t*-test under the assumption that the data are normally distributed and the variances of the two samples are equal. This is so because there is no one-to-one correspondence between the AAS and non-AAS farmers. If μ_1 and μ_2 are the population means (yield in this case) of the AAS and non-AAS farmers, $\bar{Y}_1$ and $\bar{Y}_2$ the sample means, s_1^2 and s_2^2 the sample variances, and N_1 and N_2 are the sample sizes, then we test the null hypothesis

$$H_0: \mu_1 = \mu_2,$$

$$H_a: \mu_1 \neq \mu_2,$$

Table 6. Impact of the AAS service during the study period

Crop	Season	Station	Total cost of cultivation (Rs/acre) AAS	Total cost of cultivation (Rs/acre) Non-AAS	Gross returns (Rs/acre) AAS	Gross returns (Rs/acre) Non-AAS	Benefit to cost ratio AAS	Benefit to cost ratio Non-AAS
Cereals								
Wheat	2003–04	Ludhiana	4,908.5	4,902.8	13,136.2	11,921.7	2.68	2.43
	2004–05	Ludhiana	5,201.0	5,208.1	16,221.9	14,279.7	3.12	2.74
	2005–06	Ludhiana	4,735.2	4,842.7	10,969.9	10,269.1	2.32	2.12
	2003–04	Raipur	3,701.4	3,772.1	14,375.6	13,215.0	3.88	3.50
	2004–05	Raipur	4,172.9	4,788.0	10,949.4	10,510.5	2.62	2.20
	2005–06	Raipur	3,561.7	3,135.7	13,500	11,583.6	3.79	3.69
Paddy	2003	Pantnagar	5,988.2	5,887.3	17,214.6	15,592.3	2.87	2.65
	2004	Pantnagar	4,829.3	4,774.3	14,647.1	11,564.8	3.03	2.42
	2005	Pantnagar	4,400.3	5,125.6	14,110.7	11,647.7	3.21	2.27
	2003–04	Kalyani–Boro	5,955.6	6,028.6	12,851.2	11,677.9	2.16	1.94
	2004–05	Kalyani–Boro	5,635.0	5,828.0	12,727.6	11,476.6	2.26	1.97
	2005–06	Kalyani–Boro	3,722.0	3,844.2	16,860.3	13,173.2	4.53	3.43
Millets								
Pearl millet	2004	Pune	4,332.3	3,446.2	5,435.2	3,743.9	1.25	1.09
	2005	Pune	3,734.9	3,949.2	5,980.3	5,106.4	1.60	1.29
	2006	Pune	3,686.7	3,492.6	4,864.4	4,372.6	1.32	1.25
	2004	Jodhpur	1,151.0	1,021.0	3,397.0	2,182.0	2.95	2.14
	2005	Jodhpur	1,569.0	1,326.0	4,976.0	3,708.0	3.17	2.80
	2006	Jodhpur	2,686.0	2,241.0	6,016.0	4,681.0	2.24	2.09
Vegetables								
Tomato	2004	Coimbatore	13,472.0	13,331.0	72,309.0	60,651.0	5.37	4.55
	2005	Coimbatore	15,238.0	16,508.0	58,975.0	51,569.0	3.87	3.12
	2006	Coimbatore	18,269.2	19,196.0	81,733.3	72,683.7	4.47	3.79
	2003–04	Bhubaneshwar	14,936.1	13,143.5	19,235.5	12,787.7	1.29	0.97
	2004–05	Bhubaneshwar	22,794.7	20,632.0	57,767.4	48,256.5	2.53	2.34
	2005–06	Bhubaneshwar	11,252.8	11,964.9	34,874.5	33,001.8	3.10	2.76
Palak	2003–04	Hyderabad	10,804.3	10,241.8	29,381.3	20,265.0	2.72	1.98
	2004–05	Hyderabad	33,652.1	35,963.3	102,906.3	82,588.1	3.06	2.30
	2005–06	Hyderabad	4,811.6	7,750.4	3,541.1	2,246.0	0.74	0.29
Onion	2003–04	Pune	9,726.2	10,087.6	34,225.5	24,500.1	3.52	2.43
	2004–05	Pune	10,288.2	8,870.3	24,741.0	20,562.0	2.40	2.32
	2005–06	Pune	6,344.3	6,208.3	30,387.0	24,518.2	4.79	3.95
Cash crops								
Cotton	2003–04	Coimbatore	10,623.8	12,274.8	15,543.2	16,352.3	1.46	1.33
	2004–05	Coimbatore	9,061.8	9,469.4	8,486.4	7,105.1	0.94	0.75
	2005–06	Coimbatore	8,628.5	9,201.9	15,687.5	15,304.3	1.82	1.66
	2004	Hyderabad	5,330.9	9,243.7	7,743.5	8,333.1	1.45	0.90
	2005	Hyderabad	9,736.2	11,959.5	22,063.3	22,031.6	2.27	1.84
	2006	Hyderabad	6,378.7	8,780.5	7,743.5	8,333.1	1.21	0.95
Jute	2004	Kalyani	3,352.9	3,268.8	7,402.5	6,704.3	2.21	2.05
	2005	Kalyani	4,767.6	5,890.5	21,323.7	19,952.2	4.47	3.39
	2006	Kalyani	6,146.0	6,390.0	26,702.4	24,802.4	4.34	3.88
Tobacco	2004–05	Anand	5,504.0	4,740.1	7,713.5	6,205.2	1.40	1.31
	2005–06	Anand	5,088.0	5,288.0	9,266.0	8,799.0	1.82	1.66
	2006–07	Anand	5,296.0	5,014.0	9,034.0	8,091.0	1.71	1.61
Fruits								
Banana	2003–04	Coimbatore	16,096.0	15,022.8	127,549.1	114,226.9	7.92	7.60
	2004–05	Coimbatore	31,582.8	31,131.4	83,218.8	78,992.8	2.63	2.54
	2005–06	Coimbatore	20,110.1	20,212.8	119,887.7	110,255.2	5.96	5.45
	2003–04	Thrissur	54,995.6	53,198	186,370.4	165,484.8	3.39	3.11
	2004–05	Thrissur	54,136	56,914.4	192,096	178,487.2	3.55	3.14
	2005–06	Thrissur	79,372	74,915.2	186,732	169,052	2.35	2.26

(*Contd*)

Table 6. (*Contd*)

Crop	Season	Station	Total cost of cultivation (Rs/acre)		Gross returns (Rs/acre)		Benefit to cost ratio	
			AAS	Non-AAS	AAS	Non-AAS	AAS	Non-AAS
Apricot	2003–04	Solan	3,976.8	3,541.2	57,743.1	48,518.7	14.52	13.70
	2004–05	Solan	4,934.8	2,962.3	69,722.8	40,691.5	14.13	13.74
	2005–06	Solan	5,307.3	3,826.5	69,722.8	40,691.5	13.14	10.63
Oil seeds								
Mustard	2003–04	Kalyani	3,179.2	3,145.2	10,594.7	9,993.9	3.33	3.18
	2004–05	Kalyani	3,085.4	3,163.4	9,896.8	9,187.0	3.21	2.90
	2005–06	Kalyani	3,599.3	3,943.3	11,894.0	10,197.7	3.30	2.59
	2003–04	Hisar	4,906.0	4,956.4	11,057.8	10,673.4	2.25	2.15
	2004–05	Hisar	7,375.0	4,763.8	19,501.2	9,859.9	2.64	2.07
	2005–06	Hisar	5,638.4	5,714.9	10,899.9	10,665.0	1.93	1.87
Pulses								
Gram	2003–04	Jaipur	3,240.3	3,451.2	10,037.7	9,763.2	3.10	2.83
	2004–05	Jaipur	3,871.2	3,961.9	11,927.7	11,070.8	3.08	2.79
	2005–06	Jaipur	3,672.9	3,612.3	16,019.7	14,561.6	4.36	4.03
Red gram/tur	2004	Bangalore	3,745.0	4,515.0	12,895.0	9,835.0	3.44	2.18
	2005	Bangalore	4,396.0	4,982.7	15,483.8	12,640.3	3.52	2.54
	2006	Bangalore	4,448.3	4,997.5	14,427.4	13,577.1	3.24	2.72

using the test statistic:

$$T = \frac{\bar{Y}_1 - \bar{Y}_2}{\sqrt{s_1^2/N_1 + s_2^2/N_2}}.$$

Under the null hypothesis the statistics follows a t-distribution with $N_1 + N_2 - 2$ degrees of freedom. This is then compared with the tabulated t values at 5% level of significance.

Table 7 shows the net yield (quintals/acre) of the AAS and non-AAS farmers for each crop, the calculated t values and the tabulated t values for all the stations for each category of crop, viz. cereal, millets, oilseeds, cash crops, pulses, fruits and vegetables. It is seen that in general the calculated t is more than the tabulated t for majority of the crops. This shows that the difference in the yield between the AAS and non-AAS farmers is statistically significant at 5% level of significance. The difference is more for fruit and horticulture crops. This is also corroborated from Table 6.

Tables 6 and 7 show economic impact of weather-based advisories on different crops cultivated by weather-sensitive users. Indirectly it assesses what the impacts might have been had the forecasts-cum-advisories not been available. Though the sampling method was devised to determine the direct and indirect impacts of weather-related costs and losses it was difficult to completely segregate the weather-related impacts from other factors that may also be responsible for the impact on yield. Nevertheless, considering the complexity in estimating and quantifying the user response, the survey results as given in Tables 6 and 7 provide information about the value of forecast-cum-advisory products.

In general in quantitative terms, it is seen that the AAS farmers were able to reduce the cost of cultivation by 2–5%, except in the case of fruits where the cost of cultivation has increased. This shows that the right selection of fertilizers and seeds due to organization of awareness programmes in the villages and spraying of appropriate pesticides according to the advisory saved the input costs. It was also observed that the yield increased by almost 10–15% in most of the crops, with maximum benefit in the fruit crops. Undertaking timely field operations by adoption of agro-advisories being disseminated twice a week by NCMRWF, helped in increasing the yields of various crops. The economic impact assessment is crop-specific, region-specific and season-specific.

Case studies of specific operations have also been cited with the gain/loss in economic terms in Table 8. It is seen that extreme weather can have severe impact on certain highly weather-sensitive crops. For example, at Thrissur, the banana crop is highly sensitive to heavy rainfall and wind speed. Therefore, when heavy rainfall occurred in Thrissur District against a prediction of light to moderate rainfall, the farmers incurred a loss of 12% in the overall yield. On the other hand, in Anand the tobacco farmers gained by Rs 667/acre by following the AAS of fertilizer application, as no rainfall was predicted. Table 8 gives a preliminary indication of the overall role of weather advisories in the end yield accrued by the farmer.

Table 7. Test for significance for the difference in the yield of AAS/ non-AAS farmers

Crop	Season	Station	Mean yield (quintals/acre) AAS	Mean yield (quintals/acre) Non-AAS	d*f*	Calculated *t*	Tabulated *t*
Cereals							
Wheat	2003–04	Ludhiana	32.40	29.70	78	3.93	1.98
	2004–05	Ludhiana	31.11	28.30	78	4.80	1.98
	2005–06	Ludhiana	33.64	30.33	78	5.27	1.98
	2003–04	Raipur	18.06	16.51	78	2.22	1.98
	2004–05	Raipur	15.90	14.73	78	4.09	1.98
	2006–07	Raipur	12.32	13.42	78	2.96	1.98
	2005–07	Raipur	13.80	12.50	78	2.76	1.98
Paddy	2003	Pantnagar	19.12	16.40	78	2.09	1.98
	2004	Pantnagar	19.62	15.27	78	3.12	1.98
	2005	Pantnagar	23.21	19.32	78	4.21	1.98
	2003–04	Kalyani–Boro	46.58	43.32	78	6.22	1.98
	2004–05	Kalyani–Boro	40.10	43.63	78	4.12	1.98
	2005–06	Kalyani–Boro	35.57	31.17	78	2.62	1.98
Millets							
Pearl millet	2004	Pune	23.47	18.58	38	1.72	2.02
	2005	Pune	23.18	15.58	38	2.84	2.02
	2006	Pune	12.91	11.64	38	3.34	2.02
	2004	Jodhpur	9.62	6.72	72	2.62	1.99
	2005	Jodhpur	13.68	10.72	72	1.62	1.99
	2006	Jodhpur	20.07	18.01	72	2.16	1.99
Vegetables							
Tomato	2004	Coimbatore	130.63	110.48	78	2.83	1.98
	2005	Coimbatore	110.56	98.77	78	2.94	1.98
	2006	Coimbatore	127.67	112.03	78	3.16	1.98
	2003–04	Bhubaneshwar	83.61	58.14	78	2.48	1.98
	2004–05	Bhubaneshwar	170.44	150.98	78	2.71	1.98
	2005–06	Bhubaneshwar	86.28	81.83	78	2.69	1.98
Palak	2003–04	Hyderabad	4.48	3.21	78	2.32	1.98
	2004–05	Hyderabad	16.09	12.37	78	2.78	1.98
	2005–06	Hyderabad	16.11	15.14	78	1.51	1.98
Onion	2003–04	Pune	87.76	63.86	38	8.21	2.02
	2004–05	Pune	76.15	65.75	38	4.40	2.02
	2005–06	Pune	76.72	68.79	38	5.27	2.02
Cash crops							
Cotton	2003–04	Coimbatore	7.89	6.98	78	3.44	1.98
	2004–05	Coimbatore	7.20	6.21	78	3.61	1.98
	2005–06	Coimbatore	8.25	7.81	78	3.22	1.98
	2004	Hyderabad	5.11	6.11	78	1.99	1.98
	2005	Hyderabad	10.31	10.37	78	2.34	1.98
	2006	Hyderabad	8.65	7.99	78	2.38	1.98
Jute	2004	Kalyani	21.05	19.92	78	1.32	1.98
	2005	Kalyani	36.00	30.00	78	2.38	1.98
	2006	Kalyani	38.56	34.42	78	2.29	1.98
Tobacco	2004–05	Anand	8.58	7.57	78	5.17	1.98
	2005–06	Anand	6.96	6.44	78	3.09	1.98
	2006–07	Anand	5.43	5.16	78	3.31	1.98
Fruits							
Banana	2003–04	Coimbatore	214.05	195.49	78	3.02	1.98
	2004–05	Coimbatore	172.87	157.58	78	3.23	1.98
	2005–06	Coimbatore	208.04	189.51	78	3.30	1.98
	2003–04	Thrissur	80.50	74.00	78	2.15	1.98
	2004–05	Thrissur	117.25	113.50	78	3.12	1.98
	2005–06	Thrissur	98.25	94.00	78	2.03	1.98

(*Contd*)

Table 7. (*Contd*)

Crop	Season	Station	Mean yield (quintals/acre) AAS	Non-AAS	d*f*	Calculated *t*	Tabulated *t*
Apricot	2003–04	Solan	47.54	39.40	78	2.04	1.98
	2004–05	Solan	39.91	35.65	78	2.38	1.98
	2005–06	Solan	38.27	32.56	78	4.56	1.98
Oil seeds							
Mustard	2003–04	Kalyani	6.36	6.11	78	3.28	1.98
	2004–05	Kalyani	5.87	5.65	78	1.88	1.98
	2005–06	Kalyani	7.15	6.08	78	8.92	1.98
	2003–04	Hisar	14.81	14.11	88	2.68	1.98
	2004–05	Hisar	15.59	14.59	88	7.21	1.98
	2005–06	Hisar	22.36	21.40	88	5.87	1.98
Pulses							
Gram	2003–04	Jaipur	19.80	18.17	88	1.66	1.98
	2004–05	Jaipur	17.91	16.23	88	2.23	1.98
	2005–06	Jaipur	16.72	14.57	88	2.68	1.98
Red gram/tur	2004	Bangalore	7.24	6.99	48	3.16	1.98
	2005	Bangalore	8.58	7.57	48	5.17	1.98
	2006	Bangalore	7.80	7.35	48	2.99	1.98

Table 8. Case studies of the impact of AAS

Station	Season/ operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS recommendation was followed	Loss/gain achieved due to the recommendation: Total cost of cultivation (Rs/acre)	Net returns (Rs/acre)
Thrissur Paddy	Kharif 2006 Spraying	Cloudy weather, high relative humidity and low temperature	13 and 27 June and 4 July 2006 Recommendation: Infestation of leaf folder is seen in paddy, use a thorny stick and open the folded leaves, spray Monocrotophos/ Quinalphos/Carbary	43% of farmers followed	367	850
Hyderabad Cotton	Kharif 2006 Pesticides spraying	Cloud cover, rainfall	29 September 2006 Recommendation: No rain forecast, so spray crop with Monocrotophos	Followed	3682 (26%)	4361 (39%)
Thrissur Banana (irrigated)	Rabi 2006–07 Strengthening of propping and drainage	Heavy rainfall and wind speed	20 and 27 June 2006 Recommendation: Light to moderate rainfall is expected in and around Thrissur District	Followed	Heavy rainfall occurred. Due to this extreme rainfall event there was 12% yield loss and 20.3% loss in net return	
Jaipur Gram	Rabi 2005–06 Plant protection	Minimum temperature	23 January 2007 Recommendation: Drop in minimum temperature by 3–4°C. Adopt protection against frost	Followed	250	Frost occurred. Increase by 10%
Anand Tobacco	Kharif 2005 Fertilizer application	Rainfall	15 August 2005 Recommendation: No rainfall forecast, apply recommended basal dose of fertilizer	Followed	1535	667
Jaipur Pearl millet	Kharif 2004 Fertilizer application	Rainfall	31 August 2004 Recommendation: No rainfall forecast. Top dressing of urea is suggested in view of dry weather	Followed	Light rainfalls occurred. Top dressed fertilizer wasted, loss of Rs 114.6/acre	Negative impact on net returns

Limitations of the study

As the study was designed and conducted in the most impartial way, there is a likelihood that some unexpected but unavoidable bias might have percolated into the survey. This includes sampling bias; obtaining a mutually exclusive set of AAS and non-AAS farmers regarding their awareness about weather-based agro-advisories, partial/incorrect information collected during the survey; willfully concealing information about the actual benefits accrued by the farmer; fictitious information regarding the losses suffered owing to weather, in order to obtain funds from the government. Though due care was taken to avoid such types of shortfalls/deficiencies while analysing the data collected during the survey, it is impossible to evade all of them and therefore, some of these might have influenced the final results.

Conclusion

The AAS programme of MoES is an innovative interdepartmental extension service, with a goal to deliver weather-wise management of agriculture. Although initial evaluation of AAS has been quite favourable, they have been quantitative in nature and are based on descriptive analyses of results of structured surveys. Hence more work needs to be carried out.

It may be concluded that AAS of MoES has helped in bringing out substantial awareness among farmers about adoption of weather-based advisories, their timely availability and quality of service. It has also helped in encouraging the adoption and use of modern agricultural production technologies and practices, in promoting weather-based irrigation management, pest/disease management, etc. along with greater use of post-harvest technologies and commercial marketing of commodities.

Despite positive effects of AAS on adoption of improved production technologies and practices, marginal differences were found in the yield obtained by AAS and non-AAS farmers for some crops. This may be attributed to certain other factors like shortage of capital, shortage of irrigation water, lack of adequate farmland, unfavourable weather patterns and problems of pests and diseases. These are a few aspects that highlight that the quality of advisory services is not the only vital factor that influences technology adoption and productivity, and that there is urgent need for complementary progress in other areas as well.

Scope for future work

The economic benefits of AAS should be made an integral part of AAS of MoES to recognize and acknowledge the impact of weather on different crops grown in different agro-climatic zones of the country. To accomplish this, first, the overall skill and reliability of the meteorological forecast should increase with special emphasis on extreme weather events. Secondly, efforts should be made to establish the acceptability factor among the farming community about the use of weather information-based farm advisories and the overall benefits of the service. Moreover, for successful implementation of this service, scientific agromet forecasts need blending with local technologies like traditional methods so that farmers can readily adopt and be benefited from these forecast.

India experiences a range of weather phenomena that may or may not be hazardous. These vary in both time and space scales. MoES has a key responsibility to provide weather warnings/forecasts on various weather phenomena. While the costs of providing these services are quantifiable through the budget of MoES, little effort has been made to quantify the economic benefits of the meteorological services. The success of the survey presented in this study gives an impetus to carry out similar studies in other user sectors of meteorological services such as aviation, power, etc.

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ACKNOWLEDGEMENTS. We thank Dr Shailesh Nayak, Secretary, Ministry of Earth Sciences, Government of India, for encouragement and valuable suggestions, and Drs Rahul Nigam, Sunil Kaushik and Girdhar Dewal for help in analysing the field data. We also thank our colleagues at NCMRWF for their help and support during the course of study, and the Nodal Officers and research scholars who helped in the collection of data for carrying out this study.

Received 3 September 2009; revised accepted 30 September 2011