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PROJECT REPORT

Economic Impact Assessment of Agro-Meteorological Advisory Service of NCMRWF

L.S.Rathore and Parvinder Maini

October 2008

National Centre for Medium Range Weather Forecasting
Ministry of Earth Sciences
A-50, Sector 62, NOIDA – 201307, INDIA

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Front Cover:

Front cover shows a paddy field and a farmer

Project Report

on

ECONOMIC IMPACT ASSESSMENT OF AGRO-METEOROLOGICAL ADVISORY SERVICE OF NCMRWF

L.S.Rathore & Parvinder Maini

National Centre for Medium Range Weather Forecasting

Ministry of Earth Sciences

Government of India

October 2008

Contributed by:

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MESSAGE

Weather has the most significant influence on agriculture. Besides this, extreme weather events like flood, drought/dry spell, frost, storms and even aberration in weather cause obvious impacts. It is also true that weather phenomenon such as cloudiness, precipitation, temperature, and wind have significant influence on agri-management decisions, management practices and cost of cultivation. Although a number of weather parameters are crucial to agriculture, yet the main benefit to the farmer comes from communication of critical information on weather sufficiently in advance. This helps him to adopt suitable management techniques and mitigate the ill effects on crops.

Over the years, farmers have developed numerous ways to mitigate, prepare for, and respond to the impacts of weather including long-term decision processes such as selection of crops and varieties, sowing time etc as well as short term decision processes such as time of irrigation, fertilizer application, pesticide/herbicide application. To improve the reliability of forecast, Government of India is spending huge amount of money to deploy a network of Doppler weather radars, automatic weather stations, high speed computers, wind profilers, and to modernize the National Weather Service. These new technical capabilities offer the promise of much improved forecasts. At the same time it is important for the organizations involved, to justify the spending through assessment of the economic returns of the service that they are rendering. This is essential as there is practically no reliable information on costs and benefits of weather service.

I am happy to note that NCMRWF has made one such attempt and conducted a thorough study to estimate the economic impact of the Agro-Advisory Service (AAS) that it had been managing from the 107 Agromet Field Units located in different agro-climatic zones of the country. The major objective of the study is to bring out the skill of the forecast, dissemination and outreach of the AAS service and economic assessment of the service.

I congratulate the Principal Investigator and Coordinator Dr. L.S.Rathore, and Dr. (Mrs) Parvinder Maini, the Co- Principal Investigator and Scientist In-charge for bringing out a detailed report, highlighting the results of the impact assessment along with the details of the entire execution of the study from planning, implementation to completion stage. I am sure their efforts in successful completion of the study will have far reaching effect in the overall acceptance of weather based advisories among the farming community and it will also help the planners in understanding the usability of such a study in taking tactical decisions.

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सत्यमेव जयते

GOVERNMENT OF INDIA
(Ministry of Earth Sciences)
National Centre for Medium Range Weather Forecasting (NCMRWF)
A-50, Institutional Area, Phase-II
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FOREWORD

Government of India established the National Centre for Medium Range Weather Forecasting (NCMRWF) under Department of Science & Technology (DST) in1988 with a major objective to develop numerical weather prediction based medium range weather forecast and agro-meteorological advisory services (AAS) for the farming community in India. The NCMRWF, in collaboration with the India Metrological Department (IMD), the Indian Council of Agricultural Research (ICAR) and the State Agricultural Universities (SAUS) has been providing Agro-Advisory Service (AAS) on experimental basis at the scale of agroclimatic zone to the farming community based on quantitative medium range weather forecast generated by the Centre. The country is divided into 127 agro-climatic zones with each zone covering about 4-6 districts. Beginning with 5 units in 1991, Agromet Field Units (AMFUs) have now been established in all the 127 zones of the country.

The worthiness of the service, its credibility and justification for its existence is acknowledged only if the role of the service is evaluated in terms of its economic value and benefits to farming community. An awareness of the economic value of agrometeorological information can be of great assistance in selecting decision –making strategies in agriculture. Hence, the DST had sanctioned a project entitle "Economic Impact of AAS of NCMRWF" in November 2003 for a period of 3 years to carry out a more extensive study at 15 AAS units spread in different parts of the country.

The project was planned and executed by NCMRWF in consultation with the National Center for Agricultural Economics & Policy Research (NCAP). The project was successfully completed in March 2007. This is probably the first time that a study is carried out in the country to study the impact of real time weather based advisories on the farm management decisions. 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 project is that it helped in increasing awareness among farmers about the adoption of weather based advisories and their positive impacts.

Dr. L.S.Rathore, Principal Investigator (PI) and Coordinator who was responsible for the overall planning coordination and management of the project has put in great effort towards the success of the project. I compliment him for his contribution. I also express my sincere appreciation to Dr. (Mrs) Parvinder Maini, the Co-Principal Investigator and Scientist In-charge who worked in close coordination with all the AAS units for the execution and successful implementation of the project. The 15 AAS units worked relentlessly throughout the duration of the project. I would like to record my appreciation for their special effort. The results are encouraging and provide an impetus to carry out further studies in other important sectors such as power, water work etc.

(A.K.Bohra)

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Preface

Agriculture in India depends heavily on weather and climate conditions. Weather forecasts are useful for decisions regarding crop choice, crop variety, planting/harvesting dates, and investments in farm inputs such as irrigation, fertilizer, pesticide, herbicide etc. Hence, improved weather forecast based agromet advisory service greatly helps farmers to take advantage of benevolent weather and mitigate the impacts of malevolent weather situation.

Medium range weather forecast based agro-meteorological advisory service of NCMRWF strives to improve and protect agricultural production, which is crucial for food security of the country. The weather forecast and advisories have been helping the farming community to take advantage of prognosticated weather conditions and form the response strategy. On many occasions Agro-Meteorological Field Units have reportedly saved the crop from unfavourable weather condition. Also the service, on many instances, helped farmers over different regions to minimize crop losses as a result of extreme weather conditions. Such reports were included in the Annual Progress Reports submitted by the Agro-Advisory Service (AAS) units as well as discussed during different review meetings of the project. But these were sporadic cases and could not be inter-compared mainly due to non uniform use of the methodology. Hence, a project entitled ""“Economic Impact of AAS of NCMRWF” was formulated and launched in November 2003 to assess the use and value of the service, with a view not only to assess the economic impact of the service but also to assess its usage pattern and identify strengths and weaknesses to further improve it.

The case studies include estimates for both perfect and imperfect forecasts. From a practical perspective, perfect forecasts are an unrealistic expectation, and on the other hand the less accurate forecasts also help farmers to determine farm management action and add information for decision making. Also, reporting a range of advisories which are based on weather forecasts with lower skill levels is also helpful in determining the degree of accuracy that is needed to further improve the service. Most of the economic evaluations of weather forecasts based advisories presented in the report are based on comparison of a set of information obtained from users against non-users and recorded at the individual farm level, on a per hectare basis. Majority of these studies, base the value of weather forecasts on precipitation and temperature forecasts which can aid in numerous farm level decision making strategies.

Assessing impacts of weather forecast application in farm management sector is a stupendous task. The task 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 representative sites covering principal crops. The project was implemented at 15 AAS units. The study period was spread over three years comprising of 3 Kharif and 3 Rabi seasons. National Centre for Agriculture Economics and Policy Research (NCAP), who was engaged as consultant for the project, helped to formulate the study plan, including devising sampling method, preparation of questionnaire, monitoring its implementation and data analysis. The Nodal Officers at the AAS units have carried out the study with utmost enthusiasm and zeal.

We are thankful to Secretary, Ministry of Earth Sciences (MoES) and; Secretary, Department of Science & Technology (DST); Dr AK Bohra, Head, NCMRWF for guiding and supporting the project. We take this opportunity to acknowledge the support rendered by Director General of Meteorology, IMD, Integrated Finance Divisions of DST as well as MoES and Sh Shmbhu Singh, Director, DST, for rendering support from time to time. We profusely thank all the Nodal Officers, Technical Officers, the Project Scientists at all 15 units and Dr. Rahul Nigam, Shri. Sunil Kaushik & Dr. Giridhar Dewal (Junior Research Fellows) who worked hard to accomplish this study. We also thank all the other officers, staff members and supporting personnel of NCMRWF whose names may not appear explicitly but have contributed directly or indirectly towards the preparation of this report.

L.S.Rathore
Parvinder Maini

Comments

Weather conditions play a significant role in reaping a good agricultural harvest. Variable and uncertain weather is a pervasive fact that farmers have to cope up with, and this has bearing on the livelihoods of the farm households. Timely weather information enables the farmers to plan their farm operations in a way that not only minimizes the costs and crop losses but also helps in maximizing the yield gains. NCMRWF is a national agency that generates real-time weather forecast in the medium range using advanced tools and techniques in the field of atmospheric science. These forecasts are disseminated by NCMRWF to the farming community through its network of agro-meteorological advisory service (AAS) units set up in 127 agro-climatic zones of the country. Each AAS unit prepares and disseminates AAS bulletins based on the weather forecasts received from NCMRWF and also provides user feedback as well.

The worthiness of investment for establishing a country-wide network of AAS units can be justified only if the information disseminated by these units is utilized by the farmers and is also helping them in making appropriate farm planning and management decisions. There is a dearth of empirical evidences on how the weather forecasts might contribute to the economic wellbeing of the farming community. In this context, the proactive approach of NCMRWF to take up a study on economic impact assessment of AAS is highly appreciable.

The study report begins with highlighting the significance of short and medium range weather forecasts for making adjustments in daily farm operations, followed by detailed description of how weather forecasts are generated and disseminated by the NCMRWF through its AAS units. It is logical to think that dissemination of information in vernacular languages to the farm households would have a higher degree of uptake by the target groups. One of the noteworthy aspects of NCMRWF forecasts – AAS bulletins – is that these are prepared and disseminated as location, season, weather, and crop-specific farm level advisories in local languages. These also contain information related to livestock, health and management decisions. This is made possible by the AAS units by utilizing the expertise of its multi-disciplinary teams.

With sound theoretical framework and clear objectives, the report provides an excellent impact assessment framework for capturing the farm level impacts of information used by the farmers. Though there are a number of complex tools and techniques for assessing the economic value of information use, the report rightly emphasizes identifying and estimating farm level indicators to know the impact of AAS advisories. This was necessary to effectively convey the results to the policy makers and all other stakeholders for the use of AAS bulletins.

The report assesses the impact of AAS on cereals, millets, pulses, oilseeds, fruits & vegetables and cash crops in 15 agro-ecological zones selected for the study. It is interesting to note that in most of the cases, use of AAS advisories resulted in decline in the cost of cultivation upto 25% for the study crops. In some cases, cost of cultivation did increase upto 10% as a result of follow up action on AAS advisories, but this was more than offset by the consequent increase in net returns upto 83%, with a modal value of 20%. The major crops which benefited most from the use of AAS service are paddy, wheat, pearl millet and fruits and vegetables. This proves the usefulness of AAS advisories. This also endorses the need for dissemination of AAS information to farmers on a wider scale thereby convincing them about its positive impacts on a sustainable

basis. Equally important but the most challenging task would be to enhance the accuracy of weather forecast and to make the AAS more useful and demand-driven for the farm households.

The study is a significant contribution on the use and economic impact of weather forecast. However, aggregating the impact assessment results to the level of agro-ecological zone would have added to the utility of the report. Overall, the report will serve as a benchmark to take up further studies on impact of AAS services covering all the agro-ecological regions of the country and also seeking more partners, including private agencies. The suggestions made will be useful not only to the agency and researchers, but also to the policy makers for coping up with adverse climatic conditions and designing suitable strategies for a vibrant agricultural sector.

The report is well organized and reads well. However, to make it more compact, detailed results and survey questionnaire can be presented in an Annexure.

The present study covered 15 AAS units, which were more active in dissemination of AAS. It would be useful to extend such a study by including more AAS.

The future study can also improve analytical rigour, both in terms of the indicators and analysis. For example, cost/loss analysis would be very useful to assess the real economic value of weather forecast.

Also, more caution may be exercised while attributing the changes in costs, returns and yields to the use of weather forecast, and assessing the statistical significance of changes in cost, yield, etc.

The report should be published and disseminated widely.

Dr. Suresh Pal, Dr. Harbir Singh, Dr. Anjani Kumar,
Consultants,
National Centre for Agricultural Economics and Policy Research
DPS Marg, Pusa, New Delhi – 110 012

Project Details

Title: Economic Impact Assessment of Agrometeorological Advisory Services (AAS) of NCMRWF

1.

Name of Unit	Scientist Involved	State	Agroclimatic zone
Anand	Mr. H.R. Patel; Mr. Manoj Lunagaria	Gujarat	Middle Gujarat Zone-3
Bangalore	Dr. M.B. Rajegowda; Mr. Vivekananda MB	Karnataka	Eastern Dry Zone
Bhubaneswar	Dr. Pasupalak; Mrs. Anupama Baliarsingh	Orissa	East and South Eastern Coastal Plain Zone of Orissa
Coimbatore	Dr.V. Geethalakshmi; Miss. P. Maheswari	Tamil Nadu	Western Zone of Tamil Nadu
Hisar	Dr Surender Singh Dr V U M Rao; Mr. Manoj Kr Tripathi	Haryana	Western Zone of Haryana
Hyderabad	Dr. D. Raji Reddy Dr. G.Sreenivas	Andhra Pradesh	Southern Telangana zone
Jaipur	Dr. Surendra Singh; Dr. O.P. Gill; Mr.Deependra Singh	Rajasthan	Semi Arid Eastern Plain Zone (IIIa) of Rajasthan State
Jodhpur	Dr. A.S.Rao; Dr. R.S. Singh; Mr. Bhagirath Singh; Mr. D.S. Shekhawat	Rajasthan	Arid plains of western Rajasthan
Kalyani	Dr. Gautam Saha; Mr. Nukal Mandal; Mr. Ledang Lepcha	West Bengal	New Alluvial Zone
Ludhiana	Dr. K.K.Gill; Mr.Gurwinder Singh	Punjab	Central Plain Zone of Punjab
Pantnagar	Dr H.S. Kushwaha; Dr. Amod Kumar	Uttaranchal	Tarai and Bhabar Agro - climatic Zone
Pune	Dr. R.N.Sabale; Mr.B.I. Karande;	Maharashtra	Plain zone of Maharashtra
Raipur	Dr. S.R. Patel; Mr. Somnath Choudhury	Chhatisgarh	Chhattisgarh Plain
Solan,	Mrs. Parminder Kaur Baweja; Mr. Jagdish Thakur	Himachal Pradesh	Sub-Humid, Sub-Tropical Zone of HP
Trichur	Dr. GSLHV Prasada Rao; M. V.Sudheesh N. Manikandan	Kerala	Central zone

2	P.I. of the project & Coordinator	Dr. L. S.Rathore Scientist G & Advisor MoES
3	Co-PI of the project & Scientist Incharge	Dr. (Mrs.) Parvinder Maini Scientist E, NCMRWF
4	JRF's associated with the project	Dr. Rahul Nigam, Mr. Sunil Kaushik, Dr. Girdhar Dewal
5	Consultants	Dr. Suresh Pal, Dr. Anjani Kumar, Dr. Harbir Singh, National Centre for Agriculture Economics & Policy Research
6	Implementing Institution(s) and other collaborating Institution(s):	Implementing Institutions • Anand Agricultural University, Anand • Acharya N. G. Ranga Agricultural University, Hyderabad • Bidhan Chandra Krishi Viswa Vidyalaya , Kalyani • CCS Haryana Agricultural University, Hisar • Central Arid Zone Research Institute, Jodhpur • Dr Y S Parmar University of Horticulture & Forestry, Solan • G. B. Pant University of Agriculture & Technology, Pantnagar • Indira Gandhi Krishi Vishwavidyalaya, Raipur • Kerala Agricultural University , Thrissur • Mahatma Phule Krishi Vidyapeeth, CASAM, Pune • National Centre for Agricultural Economics & Policy Research (NCAP), ICAR • Orissa University of Agriculture & Technology, Bhubaneswar • Punjab Agricultural University, Ludhiana • Rajasthan Agricultural University,Durgapura, Jaipur • Tamil Nadu Agricultural University, Coimbatore • University of Agricultural Sciences, Bangalore
7	Name of the funding agency: with sanction number and date	National Centre for Medium Range Weather Forecasting (NCMRWF) NMRF/16/15-2003 dated 3rd Nov 2003
8	Date of commencement	November, 2003
9	Planned date of completion	31st October, 2006
10	Actual date of completion	31st March, 2007

1. Introduction

Compared to various other sectors of economy, agriculture is unique, whose output is largely dependent on weather conditions. The degree of success of agriculture production and its economics is determined to a significant extent by how well weather conditions corresponding to the optimal requirements of the crop are best exploited to raise the crops. Also, how effectively adverse weather conditions, which cause moisture, thermal, wind, radiation and biotic stress impeding growth and development of crop are managed to minimize their adversity. Further to this, it also depends on management aspects of preventing the crops from severe weather conditions.

Ideally, technical progress in agriculture should reduce overall dependence on weather and climate. But the link between yield and weather/climate does not seem to be decreasing. The effects of meteorological conditions are most pronounced on high-yielding varieties of crop with increased sensitivities to environmental conditions, requiring maximum optimization of water, air, thermal and nutritional conditions. The biological potential of the plants manifests itself best in favorable conditions and is severely reduced when conditions are adverse. This results in large fluctuations in annual crop yields whose scale exceeds the increase in yields from the growth in agriculture. For this reason, the role of agrometeorological information is increasing. Using information on the effect of weather and climatic factors on agricultural productivity in an educated manner can not only reduce damage, but can also make it possible to obtain additional yield without significant financial outlays. Thus, the weather forecast based agro-advisories assumes considerable importance for agricultural activities.

For effective planning and management of agricultural practices such as selection of cultivar, sowing, need-based application of fertiliser, pesticides, insecticides, efficient irrigation and harvest, weather forecasts in all temporal ranges are desirable.Weather forecast in short and medium ranges greatly contribute towards making short-term adjustments in daily agricultural operations which minimize losses resulting from adverse weather conditions and improve yield and quantity and quality of agricultural productions.

2. NCMRWF and its Agro-meteorological services

(a) Mandate

During April-May 1983, unusual persistent cloudiness resulted in excessive losses of wheat crop. Former Prime Minister (Late) Smt Indira Gandhi suggested serious examination of variations and fluctuations in weather and exploration of ways and means to adjust the cropping pattern according to likely weather conditions. The apex committee set up to examine these aspects, recommended setting up a National Centre for Medium Range Weather Forecasting (NCMRWF) in the country having capability to forewarn farmers several days in advance. Government of India established the NCMRWF under Department of Science & Technology (DST) in early 1988 in mission mode with the following mandate;

- Development of global and regional scale numerical weather prediction (NWP) models for forecasting weather in medium range (3-10 days) time scale taking full

advantage of existing and concurrent developments both in India and abroad in the field of atmospheric science

- Set-up a state-of-the-art supercomputing infrastructure to develop suitable NWP models to issue medium range weather forecasts
- To inform and guide the farmers in advance to undertake various farming activities based on the expected weather
- Set-up agro meteorological advisory service (AAS) units, each unit representing one of the 127 agro climatic zones spread all over India, to prepare/ issue/ disseminate AAS Bulletins based on weather forecasts and to provide user feedback as well
- Set-up a stable/fast dedicated communication network with AAS units

(b) NCMRWF's operational weather forecast system

To meet the above objectives, NCMRWF has established a Global Data Assimilation and Forecasting System (GDAFS). This mainly consists of four components viz. (i) data processing, (ii) quality control, (iii) objective analysis (spectral statistical interpolation scheme) and (iv) forecast model.

The atmosphere being always in motion, mathematical equations that describe the hydrodynamical and thermodynamical properties of the fluid are utilised to describe its state. These equations are solved in steps of small increments of time, repeatedly to obtain the future state of the atmosphere in the desired time scale. To determine the future state of the atmosphere one needs to know the initial state of the atmosphere at any given point of time. The initial state is determined by a set of meteorological observations, which are taken both at surface and at different vertical levels in the atmosphere. Forecasting beyond short range necessitates the use of meteorological data from all over the globe to capture the movement and genesis of weather systems in medium range.

As part of common international agenda under the aegis of the World Meteorological Organization (WMO), all member countries of the WMO take meteorological observations at specified time and disseminate the same through Global Telecommunication System (GTS) for mutual exchange. GTS has a real-time data flow of more than 12000 surface stations, 1000 selected merchant ships and 1200 upper air stations. Beside these data a huge volume of aircraft and satellite observations are assimilated to define the initial condition of the atmosphere. Over India, in addition to the conventional data obtained via GTS, which includes observations from over 230 synoptic stations and 35-radio sonde observations, a substantial amount of non-GTS (non-conventional) meteorological data is also acquired (Das Gupta & Rizvi, 2001). This includes the Special Sensor Microwave/Imager, cloud motion winds from Kalpana (Indian satellite), and Advanced TIROS (Television and Infrared Observation Satellite) Operational Vertical Sounder (ATOVS) data. In addition some local data from 25 surface observatories and 3 upper air observatories located over north-west hilly regions of the country are also assimilated in T80 forecast system. Integration of such a huge amount of data in operational mode on real-time basis and producing the forecast in the medium range time scale is a formidable task, which can be made possible only with the help of a high speed computer. NCMRWF has the state of art supercomputers since 1988. The latest supercomputer installed at NCMRWF is the Cray-X1 E with 64 processors.

All these observations are assimilated four times a day viz. 0000, 0600, 1200 and

1800 UTC. Global data assimilation & forecast system (GDAFS) operational at NCMRWF is a six-hourly intermittent three-dimensional assimilation scheme at T80/L18 resolution along with a state of art global NWP model at same T80/L18 resolution. GDAFS utilizes all data collected within ±3-h of the assimilation time and received within a specified cut-off period (~ 12-h for 0000 UTC). After the data are processed and quality checked, data analysis is performed. The Spectral Statistical Interpolation analysis scheme used at NCMRWF is a three-dimensional multivariate analysis scheme in which data is assimilated in every 6-hour cycle (starting at 0600 UTC) to generate the initial conditions for the forecast model. The medium range forecast is then produced using the initial conditions generated for 0000 UTC. Once the forecast is obtained, it is post-processed to obtain location specific forecast. Figure 2.1 shows a schematic diagram of the GDAFS operational at NCMRWF

(c) Location Specific forecast from T80/L18 model

Weather elements like cloud amount, rainfall, maximum temperature, minimum temperature, wind speed and wind direction play an important role in agriculture and other economic activities in India. Hence, their accurate prediction is essential to make strategic decisions. The objective forecast for the above meteorological parameters is directly obtained from T80/L18 model operational at NCMRWF and is called the direct model output (DMO) forecast. However, their accuracy may be fairly low. One reason is that the NWP models are not able to resolve the local orographic features because of the various approximations under which they are developed. The other reason may be attributed to the errors in the NWP models because of coarse representation of model topography and deficiencies in model physics. The unique geographical location of India with oceans on three sides and the Great Himalayas on the fourth adds to the complexities.

Statistical-Dynamical models (SD) are developed to overcome this difficulty by developing empirical relationships between the concurrent circulation, certain thermodynamic quantities, and the resulting precipitation (Maini, 2006). The SD models incorporate numerically forecast data into a statistical prediction framework. These models provide a link between the raw output of a NWP model and weather parameters that are required in operational forecasts.

The final local weather forecast for the surface weather parameters is obtained by using information from these two types of objective forecasts and the prevailing synoptic situation around the location of interest. A group of scientists then use the information obtained above to prepare the final forecast to be disseminated to the farming community. The final forecast is a blend of objective and subjective judgement of the forecast and is hence called the man-machine mix approach (Kumar et al, 2000; Maini et al, 2004) . A forecast table designed at NCMRWF specifically for giving forecast to the user community is shown in Table 2.1.

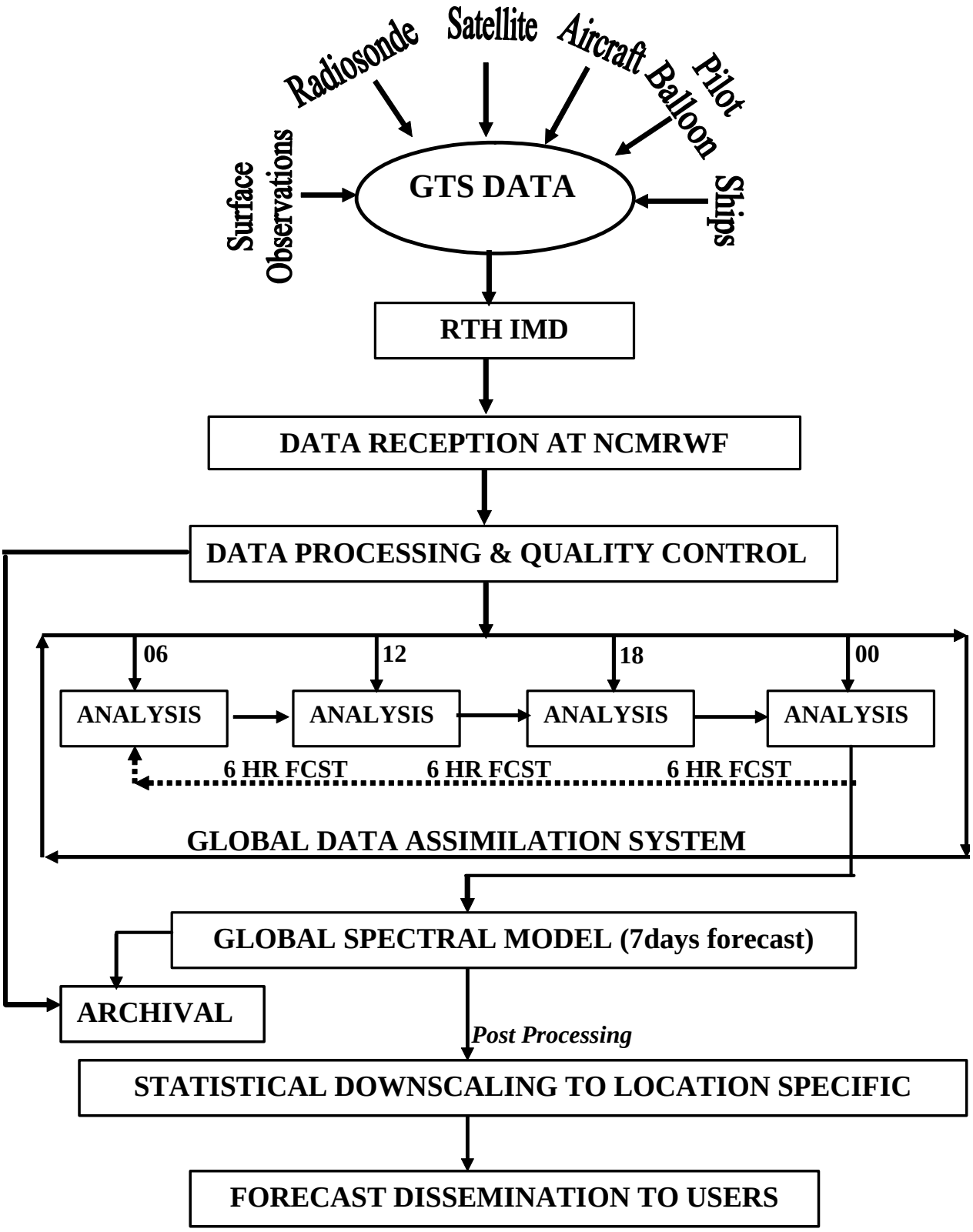

Figure 2.1: Schematic diagram showing the global data assimilation and forecast system at NCMRWF

Table 2.1. Forecast Table

NATIONAL CENTRE FOR MEDIUM RANGE WEATHER FORECASTING

Station: Delhi Date:31- 7-2007 Time: 03 GMT

Coordinates: 28.58 N 77.20 E
ALTITUDE: 229 meters
BASED UPON 00GMT ANALYSIS FOR:30-7-2007

To
NODAL OFFICER,AGRO ADVISORY SERVICE UNIT
DELHI ,DELHI

SR NO.	WEATHER PARAMETERS	DIRECT MODEL OUTPUT T-80 MODEL	DIRECT MODEL OUTPUT T-254 MODEL	STATISTICAL INTERPRETATION	FINAL
		31-7 1-8 2-8 3-8 48hr 72hr 92hr 120hr	31-7 1-8 2-8 3-8 48hr 72hr 96hr 120hr	30-7 31-7 1-8 2-8 24hr 48hr 72hr 96hr	31-7 1-8 2-8 3-8 24hr 48hr 72hr 96hr
1	MSL PRESSURE hp	1000. 1000 . 999. 997 .	997. 997. 1000. 1000.		
2	CL COVER okta E M	0 0 0 0 0 0 0 0	7 8 8 8 8 8 8 8		3 4 4 6
3	PROB. OF PRECIP. PRECIPITATIONmm PPM eqn PRECIP.	0.4 0.0 8.3 10.8	0.0 0.3 7.4 20.0	0.70 0.46 0.75 0.69 0.1 0.0 1.0 0.2 0.0 0.0 1.0 0.2	0 5 5 15
4	WIND SPEED kmph	7 7 5 5	7 15 10 14		5 5 4 4
5	WIND DIRECT.deg	158 160 161 157	101 109 124 111		160 160 160 160
6	MAX. TEMP. deg cel	36.2 36.3 35.8 35.5 1.2 0.1 -0.5 -0.3	43.6 41.3 33.2 31.4 0.4 -1.3 -8.1 -1.8	34.0 35.6 35.3 35.3 1.6 -0.3 0.0	1 0 -1 0
7	MIN. TEMP. deg cel	26.6 26.5 27.3 27.8 0.5 -0.1 0.8 0.5	32.0 28.3 26.7 25.8 -0.3 -3.7 -1.6 -0.9	27.2 27.2 26.5 27.5 0.0 -0.5 0.8	0 0 1 0
8	R.H. MAXIMUM(%)	79 80 83 89	55 78 86 93		
9	R.H. MINIMUM(%)	32 43 45 49	25 29 56 68		
10	WIND DIR. FREQ. 0---45 45---90 90---135 135---180 180---225 225---270 270---315 315---360	1.0 0.0 0.0 4.2 2.1 0.0 0.0 9.4 10.4 0.0 0.0 9.4 52.1 60.4 67.7 45.8 13.5 13.5 16.7 9.4 11.5 26.0 15.6 18.7 7.3 0.0 0.0 2.1 2.1 0.0 0.0 1.0	4.2 8.3 0.0 0.0 25.0 20.8 20.8 12.5 33.3 70.8 33.3 87.5 8.3 0.0 29.2 0.0 12.5 0.0 16.7 0.0 0.0 0.0 0.0 0.0 8.3 0.0 0.0 0.0 8.3 0.0 0.0 0.0	WEEKLY CUMULATIVE RAINFALL FORECAST FOR NEXT WEEK:- MODEL:T80: 62.5 t254: 62.7 mm , FINAL : 45mm	

(d) Agrometeorological Advisory Service of NCMRWF

One of the main objectives of NCMRWF was to give weather-based agromet advisories to the farming community. The NCMRWF in collaboration with the India Meteorological Department (IMD), Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) had been operating Agrometeorological Advisory Service (AAS) at the scale of Agroclimatic Zone till March 2007. For this NCMRWF was using the numerical weather prediction based forecasting system operational at the centre. The country is divided into 127 agro-climatic zones with each zone covering about 4-6 districts. Agromet co-ordination cells have been working at ICAR and IMD to look after the requirements of project. SAUs have appointed Nodal Officers for its smooth implementation. Agromet Advisory Bulletins comprising of expert advice on crop, soils and weather are made available to the farming community. The AAS set-up exhibits a multi-institutional multidisciplinary synergy to render an operational service for the use of farming community.

Over the past decade and a half, NCMRWF established an impressive infrastructure and also developed suitable methodologies for giving quantitative medium range weather forecasting services. Starting with 5 units in 1991, the Centre established 107 Agrometereological Advisory Services (AAS) Units in a phased manner till 2007..

The AAS units are located within SAU headquarters, their regional research stations and ICAR institutes. All these units were provided with annual Grand-in-Aid and one manpower equivalent to a Technical officer to effectively disseminate the Agromet Advisory Service and also to give its feedback to NCMRWF

AAS Units had been receiving weather forecast from NCMRWF on bi-weekly basis (Tuesday and Friday). The forecast was issued for six parameters viz., cloud amount (okta), precipitation (mm), wind speed (kmph), wind direction (degree), maximum temperature (^{o}C) and minimum temperature (^{o}C), in quantitative terms for next four days. In addition, the cumulative weekly precipitation (mm) was also provided (Table 2.1)

The Nodal Officer in charge of the AAS Unit, generally an Agrometeorologist, in co-operation with an inter-disciplinary group of agricultural and extension specialists, such as, Plant Pathologists, Soil Scientists, Entomologists, Horticulturists, Agronomists etc., formulated the agro advisories. These advisories contained location specific and crop specific farm level advisories prepared in local language containing description of prevailing weather, soil & crop condition, and suggestions for taking appropriate measures to minimise the loss and also, optimise input in the form of irrigation, fertiliser or pesticides. A format of AAS bulletin devised at NCMRWF (NCMRWF/DST, 1999) shown in Table 2.2 had been circulated to all the AAS units. This bulletin basically contained information on weather: current and past week; crop information and weather based advisories. The main stress was given to the preparation of advisories. Advisory content varied with location, season, weather, crop condition, and local management practices. All units were advised to take output from crop and pest disease models wherever possible. This helped to increase the timeliness of spraying operations, irrigation applications, fertilizer applications, etc. The advisories also served as an early warning function, alerting producers to the implications of various weather events such as extreme temperatures, heavy rains, floods, and strong winds.

The entire framework of AAS, developed and successfully demonstrated by NCMRWF has since been transferred to the India Meteorological Department(IMD) under MoES for extending the service (in operational mode) to the districts under these agro-climatic zones

Table 2.2 Format for AAB:

- *Weather Information*
  - Weather summary of the preceding week or since last bulletin including salient weather features like heavy rain, cyclones, depressions, freezing temperatures etc.,
  - Climatic normals for the week;
  - Weather forecast,
  - Crop Moisture Index, Drought severity index, etc., for the past weeks, etc.

- *Crop Information*
  - Type, state and phenological stage of crops;
  - Information on pests and diseases; and
  - Information on crop stresses.

- *Advisory*
  - Crop-wise farm management information tailored to weather-sensitive agricultural practices like sowing, irrigation scheduling, pest and disease control operations, fertilizer application. It also contain, special warnings for taking appropriate measures for saving crop from malevolent weather, if any. Information on crop planning, variety selection, selection of proper sowing/harvesting time etc. are included. Location specific package and practices for cultivation of different crops suitable for the agroclimatic zone are also provided
  - Spraying conditions for insect, weed, or disease problems
  - Problems related to animal health and their products.
  - Wildfire rating forecasts in wildfire prone areas,
  - Livestock management information for housing, health and nutrition, etc..

(e) Dissemination of forecast and bulletin

For an effective communication, NCMRWF had provided all AAS units with a fixed landline with STD facility, and a high-end personal computer with Internet facility. The forecast was disseminated from NCMRWF to the AAS units on bi-weekly basis through fax, phone and e-mail. The forecast tables were also uploaded on the NCMRWF server for easy accessibility through the ftp server.

Once the weather based AAS bulletins were prepared by the AAS units these AAS bulletins were disseminated to the farmers of the region through mass media, such as T.V., All India Radio and Newspapers in vernacular language and also through personal contact with the progressive farmers through extension workers. The bulletin was also disseminated to the contact farmers in several villages by phone, post, poster and hand delivery. Agricultural universities also conducted certain Public Awareness programmes to educate farmers about usage of Agro advisories in the farm

operation through mass media such as TV, Radio, Press and also through Kisan Mela, in which Nodal Officers of AAS units participate and make farmers aware about its usage in their farming operations. Media plays a crucial role in the dissemination of the AAS and can be taken as the nodal agency for effective outreach to the end users that is the farmer. The service, after its transfer to IMD continues to be provided with all these facilities by IMD for effective outreach. Figure 2.2 shows the complete flow diagram of the Agrometeorological advisory service of NCMRWF (NCMRWF/DST,1999)

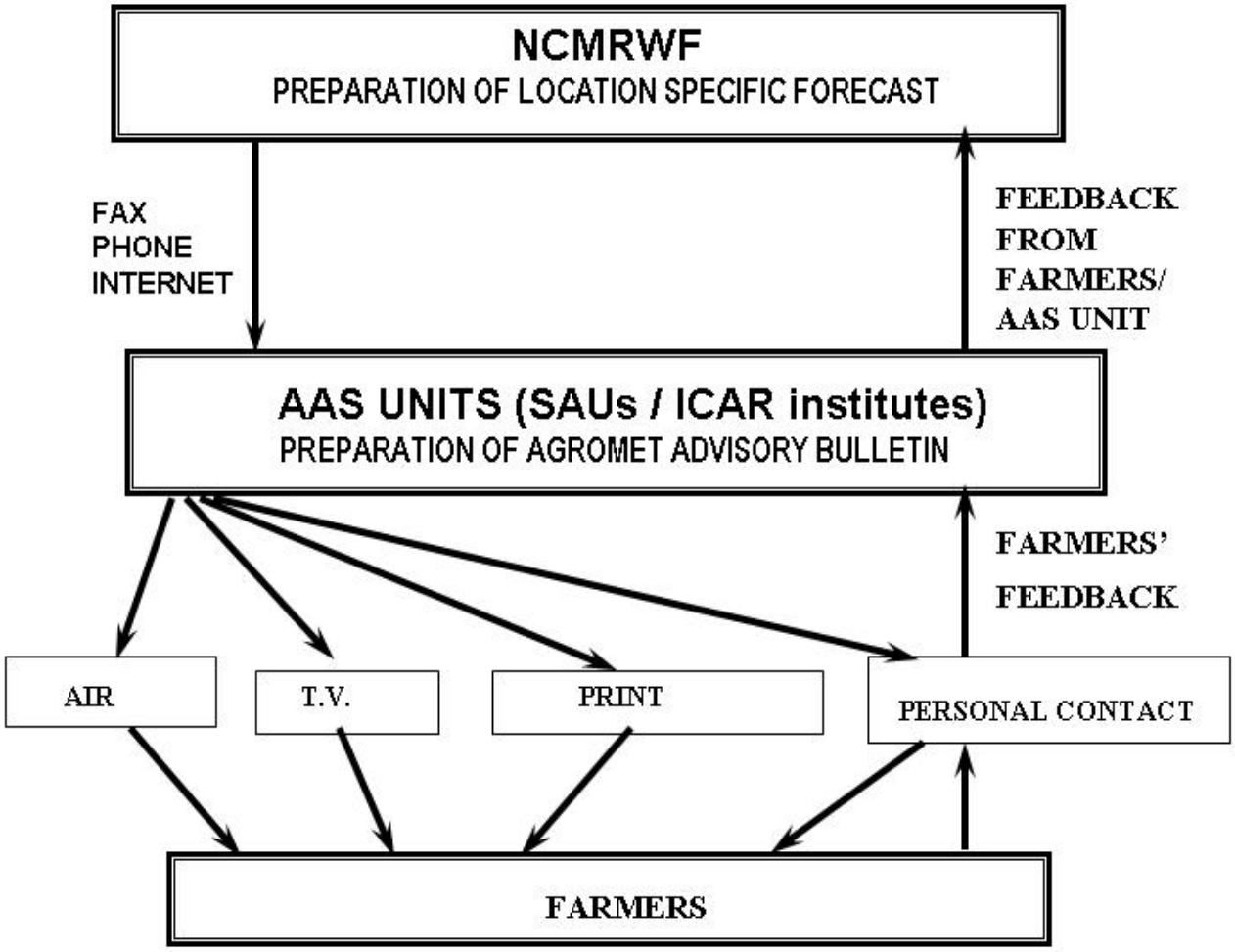

Figure 2.2. AGROMETEOROLOGICAL ADVISORY SERVICE OF NCMRWF

The status of issue of forecast/Advisory till 2007, and dissemination of advisories to the media is given in the following table:

Forecast issued to	=	107 Units
Bi-weekly forecast issued to	=	80 Units

No. of units issuing advisories	=	105 Units
No. of units Disseminating AABs to News Papers	=	93 Units
No. of units Disseminating AABs to AIR	=	70 Units
No. of units Disseminating AABs to Doordarshan	=	41 Units
No. of units Disseminating AABs to Cable TV	=	28 Units

In addition to the above NCMRWF also prepared an All India composite Agro-advisory bulletin in close collaboration with IMD with inputs from AAS units. This national composite agromet-advisory bulletin is sent to all the concerned heads of government agencies and also dispatched to the entire state government secretariat.

(f) Feedback mechanism

Periodic feedback on worthiness of forecast and usefulness of advisories is also obtained by NCMRWF. This feedback is obtained weekly, monthly and also annually. Feedback from selected farmers and Research & Development under different SAU's are being documented on whether they have adjusted their day-to-day farming operations in response to the advice laid in AAS and also on their additional requirements. Annual review meetings are conducted for the evaluation of the use of AAS and weather information. These meetings are held at different SAUs on rotation. All nodal officers from the AMFU's, and scientists from NCMRWF, IMD, and ICAR participate in this meet for the assessment of the performance of AAS units. Also, further possible ways for improvement in the existing system are discussed.

(g) Verification of Location Specific Forecast issued to AAS units

In order to evaluate the skill of the forecasts issued to the AAS units, a verification mechanism has been put in place wherein the verification is done by the service provider (NCMRWF) as well as the user community (farmers). A uniform verification procedure has been developed and circulated to all the AAS units. Therefore rigorous verification of the forecast is done as a routine for all seasons. Table 2.3 (a&b) gives the skill of forecast during the period of study (NCMRWF/DST 2005, 2006, 2007). The parameters considered here are rainfall, maximum/minimum temperature. Here the skill of rainfall occurrence/non-occurrence is given in terms of Ratio Score (*RS*) and HK Score(*HKS*) . The skill of maximum temperature (T_x) and minimum temperature (T_n) is given in terms of correlation (*CC*) and *RMSE*. The scores are mentioned in detail in Annexure-I. The verification is done during the two main seasons namely; Kharif and Rabi for all the 15 units during the period of survey. For evaluation of usability of forecast of quantitative precipitation and temperature an error structure has been formulated and is given in Annexure-I.

It is seen from Table 2.3a that while the skill of *Yes/No* rainfall forecast is around 90% during Rabi, it is around 69% in Kharif. Maximum temperature has a correlation of 65-70% and an *RMSE* of 2-3^{o}C in Kharif while in Rabi the correlation is around 60%. On the other hand the correlation of minimum temperature forecast is less in Kharif and more in Rabi season. It is around 50% in Kharif and around 65% in Rabi season. On the other hand the *RMSE* of T_n is lower than T_x and is in the range of 1-2.5^{o}C during both the seasons. The verification of wind speed, cloud cover shows that both the parameters have reasonably good skill, but the wind direction forecast needs improvement.

Table 2.3a: Skill of forecast during the study period

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

The usability of the temperature and rainfall forecast is given in Table 2.3b. While in the case of quantitative precipitation, the Rabi forecast (90-98%) is better than the Kharif rainfall (60-80%), in temperature forecast it is seen that the usability of temperature forecast is good in both the seasons with maximum temperature having higher usability in Rabi (50-90%) and minimum temperature in Kharif (60-95%).

Table 2.3b: Usability of rainfall and temperature forecast during the study period

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

3. Theoretical framework of the study

(a) Why economic impact studies?

- **User requirement**

The types of economic decision which require agro- meteorological products can be categorized according to three time scales:

- Long-term planning for agricultural development (rational allocation of land, choice of crops, selection of species and varieties)
- Medium-term planning for the next season (choice of farming area, crop varieties, etc.);
- Short-term decisions regarding imminent farming operations (choice of optimal sowing and harvest dates, dates and quantities for fertilization, dates and quantities for irrigation, etc.).

Each type of decision requires the appropriate meteorological information. In the first of the three categories listed above, this will involve basic climatological data and long-term forecasts. In the second case, it will involve seasonal forecasts, monthly forecasts, and various agrometeorological forecasts on moisture availability, yield etc. In the third case, it will involve short-term forecasts, medium-term forecasts, and special recommendations for crop-growth. In the present study, the problem has been addressed only to the third requirement of the user.

- **Service requirement**

Internal perspectives

- To establish the worthiness of the service: Economic impact has to be carried out in order to know its potential benefits.
- Service credibility: Credibility is always closely linked to forecast verification. Hence, economic impact studies need to be carried out to establish credibility in the eyes of the potential users if optimum benefits are to be derived from the marketing of the service.
- Service accountability or justification: Assessment of the service helps justifying the costs and the ongoing need and existence of such a service.

External perspectives

- By quantifying the benefits of this service one comes to know the needs of the users, their level of satisfaction and their further expectation. Consequently the progressive user provides a positive feedback & increased response of progressive users drive the service. The outcome includes better services over time, services with better utility and most likely with better-perceived accuracy. Secondly, through these interactive educational initiatives, policy makers and other clients become sensitized to and better informed about the value of these services, which results in improved decision making.

National perspective

- On the national scale, more knowledgeable decision-making leads to improved practices and attitudes, enhanced productivity, a more nationally relevant economic society and more socially acceptable practices.

(b) Agromet Impact Study Paradigm

In general it is difficult to assess the economic benefit of any advisory service given to take measure against catastrophes or life threatening situations, but it is possible to assess the economic benefit of the agrometeorological services (Nicholls,1996). Although there does not exist any general simulation model for the evaluation of the economic benefits of meteorological assistance to agriculture, however three points can always be defined:

- evident effective benefit
- probable effective benefit
- theoretically maximum possible benefit

Figure 3.1 shows a schematic diagram to study the impact of agro-meteorological information on agriculture

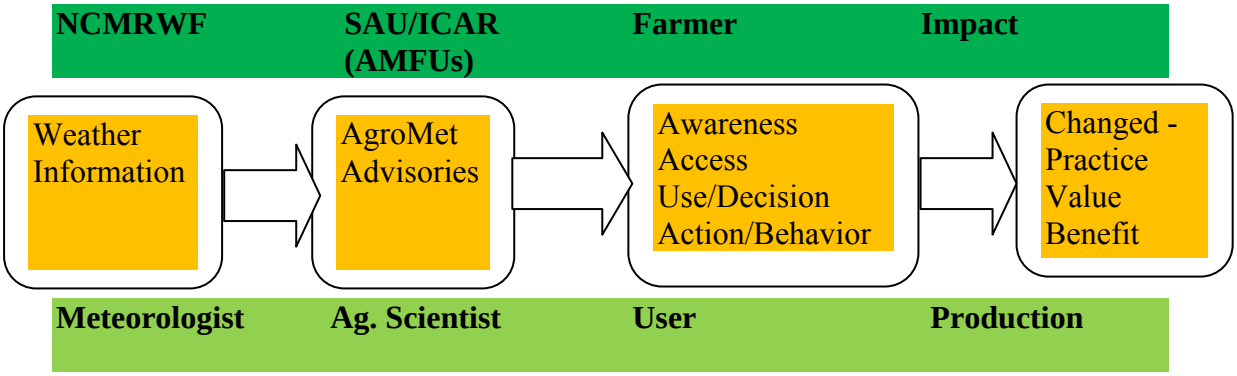

Figure 3.1: A schematic diagram to show the impact of agromet services

Weather information content which is part of the advisory bulletin should contain information on what is going to happen (precipitation, temperature, cloud, wind) and when is it going to happen at the given area of interest to the farmer. The information is disseminated through mass media dissemination agencies including internet, Radio / TV and Phone/Fax.

Weather information is translated into farm level action oriented advice by the agricultural scientists at AgroMeteorological Field Units. It contains weather based advisories including time and method of sowing, time and amount of irrigation, time and method of fertilizer/pesticide application etc.

Agriculture impacts include changes experienced by farmers that have meaning or value positive (a benefit effect) or negative (an undesired effect) helping them to decide 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 the AAS units.

(c) Preliminary work

Once the outreach of the service and skill of the forecast was established, it was pertinent to study the impact of the service in terms of economic gain/loss. It was felt that an awareness of the economic value of agrometeorological information can be of significant assistance in selecting decision-making strategies in agriculture. Hence, AAS units were directed to assess the economic benefits accrued due to AAS. Some of the units reported the benefits accrued by the farmers, but mostly in qualitative terms.

The AAS units assessed the Economic Impact in their own way and the results could not be inter-compared due to absence of uniform impact criteria. For example, the farmers of Kovilpatti (Tamil Nadu) region adopted weather based advice of early sowing of Sorghum, Cotton and Pulses as good rainfall was predicted during 3rd week of September 1995 nearly 20 days before the normal date of commencement of North-East monsoon rainfall. They received nearly 50% increase in yield in all the three crops. On the other hand, the farmers of Pune region who could not follow the advice on delayed onset of southwest monsoon faced complete failure of crop due to inadequate moisture for germination. Farmers of Ludhiana could save 30% of the total production of Potato and Tomato due to frequent and light irrigation of the crop as the NCMRWF predicted occurrence of frost on account of considerable fall in the minimum temperature. For Coimbatore, advisories on strong winds during July, 1995 have helped saving standing Banana crop worth Rs 10,000 per acre. The farmers of Raipur could save up to Rs.5000/- in the case of Chilly and up to Rs 10,000/- in the case of Potato per hectare due to skipping of one irrigation after heavy rainfall forecast at crucial phenophase of the crops. Following the wind speed and direction forecasts, they saved at least 20% cost of the insecticides. At Chennai, specific instances have shown that by timely forecast of rainfall, farmers could prevent spoilage of feed, chick mortality, coccidiosis, lung infection among birds and other bacterial infections.

Although there existed some awareness about the impact of the weather based agro advisories on the farming community, but there was lack of a clear and precise understanding of the impact. Therefore there was a need to carry out this impact assessment study using specified impact criteria and with a uniform pattern of study

(d) Benefits or expectations from these studies

Although the AAS units had been making concerted efforts to carry out economic impact of the service provided by NCMRWF, yet an urgent need was felt to put in more serious efforts and to have a uniform procedure for assessing the economic impact of the service. Hence, to carry out a more extensive study DST launched a pilot project entitled “Economic Impact of AAS of NCMRWF” in the year 2003. In order to have an evaluation of the AAS at different agroclimatic zones and different weather conditions, 15 AAS units in different parts of the country were chosen. The project was spread over three years covering 3 Kharif and 3 Rabi seasons. National Centre for Agricultural Economics & Policy Research (NCAP) was given consultancy for preparing concept note, questionnaire, methodology and final review of the reports prepared by the AAS units/NCMRWF. NCMRWF on its part

was responsible for conceptualizing and executing the study, providing grants and bringing out the final report. Therefore, 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 taking better decision. Application of these methods for assessing economic and social benefits can produce information leading to the efficient production and supply of services,
- Will help in cultivar selection, their dates of sowing/planting/transplanting, dates of intercultural operations, dates of harvesting and also performing post harvest operations,
- Will give site-specific forecast information and corresponding advisories that will help maximize output and avert crop damage or loss. The service will also help growers anticipate and plan for chemical applications, irrigation scheduling, disease and pest outbreaks and many more weather related agriculture-specific operations,
- Will give agromet advisories that will increase profits by consistently delivering actionable weather information, analysis and decision support for farming situations such as:
    - To manage pests through forecast of relative humidity, temperature and wind,
    - Progressive water management through rainfall forecasts,
    - To protect crop from thermal stress through forecasting of extreme temperature conditions.

Above all, along with many other situations the study will help increase the crop protection, hence knowledge needs to improve the bottom line, protect resources and preserve the environment.

(e) Objective of the study

The prime intent of the study was to assess use and value of the agro-advisories which are based on four day quantitative weather forecast for important meteorological elements at the scale of the agroclimatic zone. It encompasses the aspects related to the skill of weather forecast (Katz & Murphy,1997), quality and relevance of the forecast based advisories, acceptance by the user community, user satisfaction leading to its consumption and ultimately quantifying the benefits/losses accrued due to implementing the advisories for managing a wide spectrum of crop situations spread over different agroclimatic zones of the country. It also includes the related components of AAS such as dissemination of the bulletins, out reach of the service, and capacity of the user community in adapting the advisories by different sections of the society under varying education, gender & socio-economic classes. The prime objectives are as under;

- Adoption of the forecast by the user community and its realization. It further helps to understand the linkages between information, users and impacts
- To assess the effectiveness and potential benefits of Agro-Advisory services by taking into account the AAS contact and non-contact farmers.
- To work out weather based farming strategies based on the economic impact of Agromet Advisory Services.
- To account and assess the needs of the farming community for increasing the farm produce.

- To assess the economic impact of the AAS services in various crops under different ago climatic conditions.

The Economic Impact of AAS, however does not cover the evaluation of the capacity and methods of weather forecasts, which is beyond the scope of this study. The impact assessment framework entails reliability and adequacy of weather forecasts, mechanism of flow of weather information, extent of use of weather by farmers and economic and other impacts.

(f) Concept of the study

The concept of the study is based on the

- Assessment of ability of forecast based advisory to influence farmers' decisions on
  - Selection of cultivar
  - Selection of optimum sowing time
  - Conducting farm operation in tune with weather forecasts leading to energy saving, enhancing the efficacy of inputs such as fertilizer, pesticides etc.
  - Cutting costs of agriculture inputs such as pesticide, irrigation, fertilizer, herbicide etc.
  - Saving of crop from adverse weather
- Find out Economic and other benefits due to use of forecast in farm management decisions
- Determine the saving the crop from adverse weather
- Assessing impact of favorable weather on overall growth, development and final yield of the crop.

(g) Impact Assessment Analysis Framework

A number of approaches and methods have been used in the literature to assess the value and impact of weather forecast. Important among these are assessment of the value of weather forecast, economic benefits to farmers or individual farms, and economic and social benefits for a sector or country as a whole. The cost-loss analysis, expected utility approach, stochastic programming approach, simulation model, economic surplus, and computable general equilibrium model are most frequently used methods.

The selection of analytical method is determined by objective of the study, availability of required data and computational skills. Since main objective of the study is 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 most appropriate. In the present study, the selection of method is also influenced by the fact that policy makers can easily understand the results and the method can be applied with moderate analytical skill. Therefore, NCAP proposed use of simple farm-level indicators for the impact assessment. The impact assessment framework proposed included estimation of accuracy of the forecast, adequacy and reliability of the forecast from farmers' perspective, use of the forecast, and farm-level impacts.

Table 3.1 describes the framework to be followed for assessing the usefulness of weather forecast through the survey and Table 3.2 gives the economic impact indicators to be considered

Table 3.1: Use of Weather Forecast

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

Table 3.2: Economic Impact Indicators

Parameters	Indicators
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 maneuvering cultural operations

(h) Sample selection

Considering the importance of the sampling in the study, care was taken to identify the sample which is true representative of the class. Thus the farmers were selected based on their size of holding (small, medium, large), educational background, size of the family, types of crops grown. Section 4 gives the demographic details of the samples chosen by each unit. As it was difficult to collate information from a very large or not-interested farmers the sampling was done based on the following criterion.

- 15 AAS units out of a total 127 were chosen based on the existence of an effective weather based agro-advisory service of NCMRWF at the unit for quite some time.
- 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, 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.
- In each selected villages, a list of all the AAS contact farmers was prepared by category of their size of holding (small, medium, large), educational background, family size, type of crops 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 the 2 villages.

Similarly, a list of villages having no AAS contact farmer from the same district were prepared and two villages were chosen. From the two selected villages, a list of all the farmers (non- AAS contact farmers) was prepared based on the criteria described above. 20 farmers were then selected by random sampling from each village. Thus in summary. four villages comprising of 2 villages of AAS contact farmers and 2 villages of non-AAS contact farmers were selected at each of the 15 units chosen for the study. 20 AAS and 20 non-AAS contact farmers were selected from each village, thus making a sample of 80 farmers (40 AAS and 40 non-AAS).

In order to keep the data of manageable size, information on important crops (at least one each for Kharif and Rabi, but not more than four crops was selected for taking detailed information on use and impact of weather forecasts. To ensure reliability of the results, data has been collected for 3 Rabi and 3 Kharif seasons viz., Kharif 2004, 2005 and 2006 and for Rabi 2003-04, Rabi 2004-05 and Rabi 2005-06. As most of the units could not collect the data for Rabi 2003-04, hence the project was extended by 6 months to accommodate the Rabi season of 2006-07.

(i) Survey & the questionnaire

The sampling method was designed to work directly with the users of forecast and advisory information, to be able to more meaningfully assess credible cost/loss estimates. The important issue was to develop effective and meaningful base for assessing 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 the pesticide applications. To obtain quantitative information, working relationships between AMFUs and user farmers were set up through periodic visits. Through such visits input from the farmers were obtained about use and application of the advisory bulletins through pre-devised questionnaire. Thus the sample survey is not independently conducted by the agency which provided the questionnaire and therefore a certain amount of bias in inevitable. This has been highlighted in Section 9 as one of the limitations that has been encountered during the study.

The AAS units gave special attention to date of sowing, planting, harvesting, spraying, irrigation and tillage operation. Due attention was paid to collecting information on the adoption of advisory by the farmers during such operations and the benefit/loss accrued by the farmers by following/not-following advisories related to such crucial operations.

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

- Socio- Economic Status: The socio -economic status of the farmers is surveyed using the queries related to the following in the questionnaire
  - Family structure
  - Literacy among farmers

- Size of land holding
- Cropping pattern
- Traditional Methods used
- Mode of irrigation
- Awareness of AAS
- Mode of receipt of AAS
- Weather parameters required
- Satisfaction from service (reliability, timely availability, expected benefits, frequency)
- Willingness to pay

- Quantity analysis of inputs used
  - Quantity of Seed, Fertilizer, Pesticide
  - No: of Labour (Human, machine)
  - No: of Irrigations
- Price analysis of inputs used
  - Price of Seed, Fertilizer, Pesticide
  - Cost of labour (Human, machine)
  - Cost of Irrigation
  - Cost of product/byproduct
  - Any other associated cost

(j) Crops selected by the units

The major crops chosen for the study are as under

- 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
- Vegetables: Tomato and Spinach.

(k) Format of the questionnaire / Farm Survey schedule

Date of interview (dd/mm/yyyy): [ ] *Schedule Number*: [ ]

Part I. General Information

1. Name of the AAS unit: _____ (V1)
2. Name of agro-climatic zone: _____ (V2)
3. Name of district: _____ (V3)
4. Name of sample village: _____ (V4)
5. Name of farmer (Decision-maker): _____ (V5)

6. Farmers' age (years): _____ (V6)

7. Sex: Male (1)/ Female (2): _____ (V7)

8. Years of schooling: _____ (V8)

9. Persons (adults) dependant on agriculture: _____ (V9)

10. Distance of the village from AAS unit (km.): _____(V10)

11. Size of operational holding (acres): _____(V11)

12. Leased-in land (acres): _____(V12)

13. Leased-out land (acres): _____(V13)

14. AAS contact farmer Yes (1)/ No (2): _____(V14)

Part II. Farmer's assessment of weather forecasts (reliability and use)

1.What are the weather-related events affecting crops adversely during the last 10 years?

Crop		Most affected stage		Second most affected stage	
		Stage*	Weather parameter**	Stage*	Weather parameter**
1	V15	V16	V17	V18	V19
2.	V20	V21	V22	V23	V24
3.	V25	V26	V27	V28	V29
4.	V30	V31	V32	V33	V34
5.	V35	V36	V37	V38	V39

*1-Sowing; 2-Vegetative growth; 3-Flowering; 4- Maturity; 5-Harvesting
** 1-Rainfall; 2- Temperature; 3- Wind speed; 4- Wind direction; 5- Cloud cover; 6- Any other

2. What are your sources (three most important) of weather forecasts? Please tick that is relevant.

a. Radio V40
b. Television V41
c. Newspaper V42
d. AAS Bulletin in printed form/ Public notice V43
e. Telephone/ Fax / Personal contact with AAS V44

f. Any other, please specify V45

3. What is the frequency of forecasts you use?

a. Daily V46
b. Bi-weekly V47
c. Weekly V48
d. Fortnightly V49
e. Monthly V50
f. Seasonally V51

4. What is the coverage of forecast used by you?

a. Rainfall V52
b. Temperature V53
c. Wind speed V54
d. Wind direction V55
e. Cloud cover V56
f. Any other V57

5. What are traditional weather forecast methods followed by you?

Parameters	Method#	Length of forecast (daily/weekly/monthly/ seasonal/other)*	Chances of hit forecast (%)
Rainfall	V58	V59	V60
Temperature	V61	V62	V63
Wind speed	V64	V65	V66
Wind direction	V67	V68	V69
Cloud cover	V70	V71	V72

1- Observing star positions; 2- Consulting *Panchang* (Horoscope); 3- Folklore; 4-Any other
*1- Daily; 2- Weekly; 3- Monthly; 4- Seasonal; 5- Other (specify)

6. Are you aware about AAS Bulletins: Yes(1)/ No (2) _____ V73

7. If yes, how did you come to know about the AAS bulletins? V74
a. Personal contact with officials (Scientist, AAS field staff, BDO) V75
b. Informed by fellow farmer or *Panchayat* head V76
c. Through electronic media: (Radio-1; TV –2) V77
d. Through mass media: (Newspaper): V78
e. Any other source? V79
f. How do you define it? V80

8. A. AAS Bulletin provides weather forecast for:

a. Rainfall V81
b. Temperature V82
c. Wind speed V83

d. Wind direction V84
e. Cloud cover V85
f. Multiple weather parameter V86
g. Farm management V87
h. Multiple weather parameter and farm management V88

B. Duration of forecast V89
a. Daily (1)
b. Bi-weekly (2)
c. Weekly (3)
d. Monthly (4)
e. Seasonal (5)

9. Since when you are receiving the AAS Bulletins (month / year): V90

10. To what extent the message of AAS bulletin is clear and adequate? V91

a. Coverage is adequate (Yes -1/ No -2) V92
b. Message is clear (Yes-1/ No -2) V93
c. Is additional information on crop management useful? (Yes-1/ No-2) V94
d. Is frequency of dissemination all right? (Yes- 1/ No -2) V95

11. What are the factors having bearing on the importance of AAS Bulletin V96

a. Timely availability: (Yes-1/ No-2) V97
b. Forecast reliability: (Yes-1/ No-2) V98
c. Expected benefits: (Yes-1/ No-2) V99
d. Overall usefulness (most useful-1, somewhat useful- 2, useless- 3): V100

12. If you are satisfied with AAS bulletin, are you willing to pay for it? V101

Yes-1/ No- 2/ Can't say –3

13. If Yes, what maximum price can you pay for the AAS bulletin for one crop season (indicate in terms of kilogram of crop produce)? V102

Sl.No.	Crop	Kilogram of crop produce	
1			V103
2			V104

Provide information for the two most important crops.

14. Suggestions for improvement in AAS:

a. Coverage should V105
   i. Increase (specify in days):
   ii. Decrease (in days specify):
   iii. Not change

b. Frequency should V106
   i. Increase (in days specify):
   ii. Decrease (in days specify):
   iii. Remain unchanged

c. Lead time (time available between availability of forecast & taking action) should: V107
   i. Increase (specify in days):
   ii. Decrease (in days specify):
   iii. Remain unchanged

d. Length of forecast should V108
   i. Increase (specify in days):
   ii. Decrease (in days specify):
   iii. Remain unchanged

e. Agro advice should have more focus on V109
   i. Latest technological know-how (variety, breed, etc)
   ii. Input use
   iii. Plant protection
   iv. Market-related information
   v. Any other

f. Rank the following based on their effectiveness in information dissemination: V110
   i. Electronic media (TV, Radio, etc) V111
   ii. Print media (Newspapers, Magazines, etc.) V112
   iii. Any other method (please specify) V113

g. Any other information V114

Part III.

15. Cropping pattern and area under important crops: (for total operational holding)

Crop	Area irrigated (acre)	Source of irrigation (canal/tube well/ well/other)*	Un-irrigated area (acre)	Area under HYV** crops (acre)
Kharif				
1 V115	V116	V117	V118	V119
2 V120	V121	V122	V123	V124
3 V125	V126	V127	V128	V129
4 V130	V131	V132	V133	V134
5 V135	V136	V137	V138	V139
Rabi				
1 V140	V141	V142	V143	V144
2 V145	V146	V147	V148	V149
3 V150	V151	V152	V153	V154
4 V155	V156	V157	V158	V159
5 V160	V161	V162	V163	V164

*1-canal; 2-tubewell; 3-wells; 4-others; ** HYV= High Yielding Varieties (of crops)

Use of weather forecast, Input use pattern and crop yield:

Farmer's name:V5 Village: V4 District:V3 Date of Interview: V165

Plot No. V166_____Area (acre) V167 _____ Own/ Lease[1] V168 ____ If irrigated, source of irrigation[2] : V169 … Unirrigated/Rainfed V170 ….

Crop V171 _____Variety V172 _____ Previous crop grown V173 _____

Operations	Land preparation	Seed treatment	Sowing	Irrigation/Drainage					Fertilizer/ FYM application	Plant protection	Interculture	Harvesting	Threshing	Post harvest handling and storage
	V174	V194	V214	1 V234	2 V254	3 V274	4 V294	5 V314	V334	V354	V374	V394	V414	V434
Crop growth stage	V175	V195	V215	V235	V255	V275	V295	V315	V335	V355	V375	V395	V415	V435
Nature of weather risk	V176	V196	V216	V236	V256	V276	V296	V316	V336	V356	V376	V396	V416	V436
Date of operation	V177	V197	V217	V237	V257	V277	V297	V317	V337	V357	V377	V397	V417	V437
Method of operation, if applicable	V178	V198	V218	V238	V258	V278	V298	V318	V338	V358	V378	V398	V418	V438
Use of AAS: (Yes–1; NO-2)	V179	V199	V219	V239	V259	V279	V299	V319	V339	V359	V379	V399	V419	V439
AAS recommendation	V180	V200	V220	V240	V260	V280	V300	V320	V340	V360	V380	V400	V420	V440
Action taken by you	V181	V201	V221	V241	V261	V281	V301	V321	V341	V361	V381	V401	V421	V441
Reasons for deviation[3]	V182	V202	V222	V242	V262	V282	V302	V322	V342	V362	V382	V402	V422	V442
Associated cost[4] (Unit)	V183	V203	V223	V243	V263	V283	V303	V323	V343	V363	V383	V403	V423	V443
Input name	V184	V204	V224	V244	V264	V284	V304	V324	V344	V364	V384	V404	V424	V444
Input quantity	V185	V205	V225	V245	V265	V285	V305	V325	V345	V365	V385	V405	V425	V445
Male labour use (mandays)[5]	V186	V206	V226	V246	V266	V286	V306	V326	V346	V366	V386	V406	V426	V446
Female labour use (mandays)[5]	V187	V207	V227	V247	V267	V287	V307	V327	V347	V367	V387	V407	V427	V447
Machine use (Hrs.)	V188	V208	V228	V248	V268	V288	V308	V328	V348	V368	V388	V408	V428	V448
Machine (Type)	V189	V209	V229	V249	V269	V289	V309	V329	V349	V369	V389	V409	V429	V449
Bullock use (Pair Hrs.)	V190	V210	V230	V250	V270	V290	V310	V330	V350	V370	V390	V410	V430	V450
Main Product (Qtls.)	V191	V211	V231	V251	V271	V291	V311	V331	V351	V371	V391	V411	V431	V451
By Product (Qtls.)	V192	V212	V232	V252	V272	V292	V312	V332	V352	V372	V392	V412	V432	V452
Remarks (Any extreme event at any stage; Other)	V193	V213	V233	V253	V273	V293	V313	V333	V353	V373	V393	V413	V433	V453

NB: Kindly see the 'Explanatory Note' for filling up the numbered columns.

Use of weather forecast, Input use pattern and yield: (Fruits and Plantation Crops)

Farmer's name:V5 Village:V4 District: V3 Date of Interview: V165 Plot No

V166_____Area (acre) V167 _____ Own/ Lease[1] V168 _____ If irrigated, source of irrigation[2] V169 .. Unirrigated/Rainfed V170 ……..

Crop V171_____ Variety 172 _____ Previous crop grown V173 _____ Age of plantation (Years) V454 _____

Operations	Operations*									
	Interculture	Pest management	Irrigation					Fertilizer application	Harvesting	Post-harvest management
			1	2	3	4	5			
	V455	V474	V493	V512	V531	V550	V569	V588	V607	V626
Nature of weather risk	V456	V475	V494	V513	V532	V551	V570	V589	V608	V627
Date of operation	V457	V476	V495	V514	V533	V552	V571	V590	V609	V628
Method of operation	V458	V477	V496	V515	V534	V553	V572	V591	V610	V629
Use of AAS: (Yes – 1; NO -2)	V459	V478	V497	V516	V535	V554	V573	V592	V611	V630
AAS recommendation	V460	V479	V498	V517	V536	V555	V574	V593	V612	V631
Action taken by you	V461	V480	V499	V518	V537	V556	V575	V594	V613	V632
Reasons for deviation[3]	V462	V481	V500	V519	V538	V557	V576	V595	V614	V633
Associated cost[4] (Unit)	V463	V482	V501	V520	V539	V558	V577	V596	V615	V634
Input name	V464	V483	V502	V521	V540	V559	V578	V597	V616	V635
Input quantity	V465	V484	V503	V522	V541	V560	V579	V598	V617	V636
Male labour use (mandays)[5]	V466	V485	V504	V523	V542	V561	V580	V599	V618	V637
Female labour use (mandays)[5]	V467	V486	V505	V524	V543	V562	V581	V600	V619	V638
Machine use (Hrs.)	V468	V487	V506	V525	V544	V563	V582	V601	V620	V639
Machine (Type)	V469	V488	V507	V526	V545	V564	V583	V602	V621	V640
Bullock use (Pair Hrs.)	V470	V489	V508	V527	V546	V565	V584	V603	V622	V641
Main Product (Qtls.)	V471	V490	V509	V528	V547	V566	V585	V604	V623	V642
By Product (Qtls.)	V472	V491	V510	V529	V548	V567	V586	V605	V624	V643
Remarks (Any extreme event at any stage; Others)	V473	V492	V511	V530	V549	V568	V587	V606	V625	V644

NB: Kindly see the 'Explanatory Note' for filling up the numbered columns.

Operations*: Interculture, post-harvest management, irrigation, fertilizer application, harvesting, post-harvest management etc. Please note that all farm applications may not be relevant during a visit.

Explanatory Notes:

1. Owned land/ Leased in land
2. 1-.Canal, 2- Tubewell, 3- well 4-Others
3. 1-Unreliable forecast; 2- Inadequate time; 3- Inadequate resources; 4- Uncertainty of expected benefits; 5- Recommendation not feasible; 6- Any other
4. Additional non-input cost (Rs)
5. One man equivalent day equals to 8 hours.
6. Since the field investigator is supposed to observe farmers' responses to AAS Advisory on weekly basis, the farmers' response would be captured at different crop growth stages viz., Vegetative, Flowering, Fruiting, Ripening, Harvesting.
7. This information will be collected during several visits to farmers. Please use one sheet for a crop. If environments like irrigated and rainfed, then separate sheets should be used. The data then will be transferred to a master sheet.

General information about prices

Sr. No.	Items			Price / Rate (Rs./ Unit)	Remarks
1.	Seed		(Rs./kg)	V645	V646
2.	Fertilizer (1)		(Rs./kg)	V647	V648
	(2)		(Rs./kg)	V649	V650
	(3)		(Rs./kg)	V651	V652
3.	Irrigation charges		(Rs./acre)	V653	V654
4.	Labour		(Rs./mandays)	V655	V656
5.	Machine Labour (1)		(Rs./acre)	V657	V658
	(2)		(Rs./acre)	V659	V660
	(3)		(Rs./acre)	V661	V662
6.	Bullock Labour		(Rs./acre)	V663	V664
7.	Plant Protection chemicals (1)		(Rs./acre)	V665	V666
	(2)		(Rs./acre)	V667	V668
	(3)		(Rs./acre)	V669	V670
8.	Product prices	Main product	(Rs./qtl)	V671	V672
		By product	(Rs./qtl)	V673	V674

Note: This information will be compiled in first year for a farmer, and all analysis will be done at these (constant) prices.

4. Survey results of socio-economic features of farmers

For the purpose of comparison of the socio-economic features of household, India was divided into 4 zones north (Ludhiana, Hisar, Pantnagar, Solan); West (Jaipur, Jodhpur, Anand, Pune); East (Raipur, Nadia, Bhubaneshwar); and south (Bangalore, Hyderabad, Coimbatore, Thrissur). The survey has been conducted based on the questionnaire designed by NCAP.

(a) Age group of farmers

The pie graph shown in Figure 4.1 below 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 or more (83%) followed by east where it is 61% and this is followed by north where 57% of the farmers are in this age group. In the west consisting of station like Jaipur, Jodhpur, Anand and Pune 47 % of the farmers are less than 35 years of age. In general, it is seen that on an average over India 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.

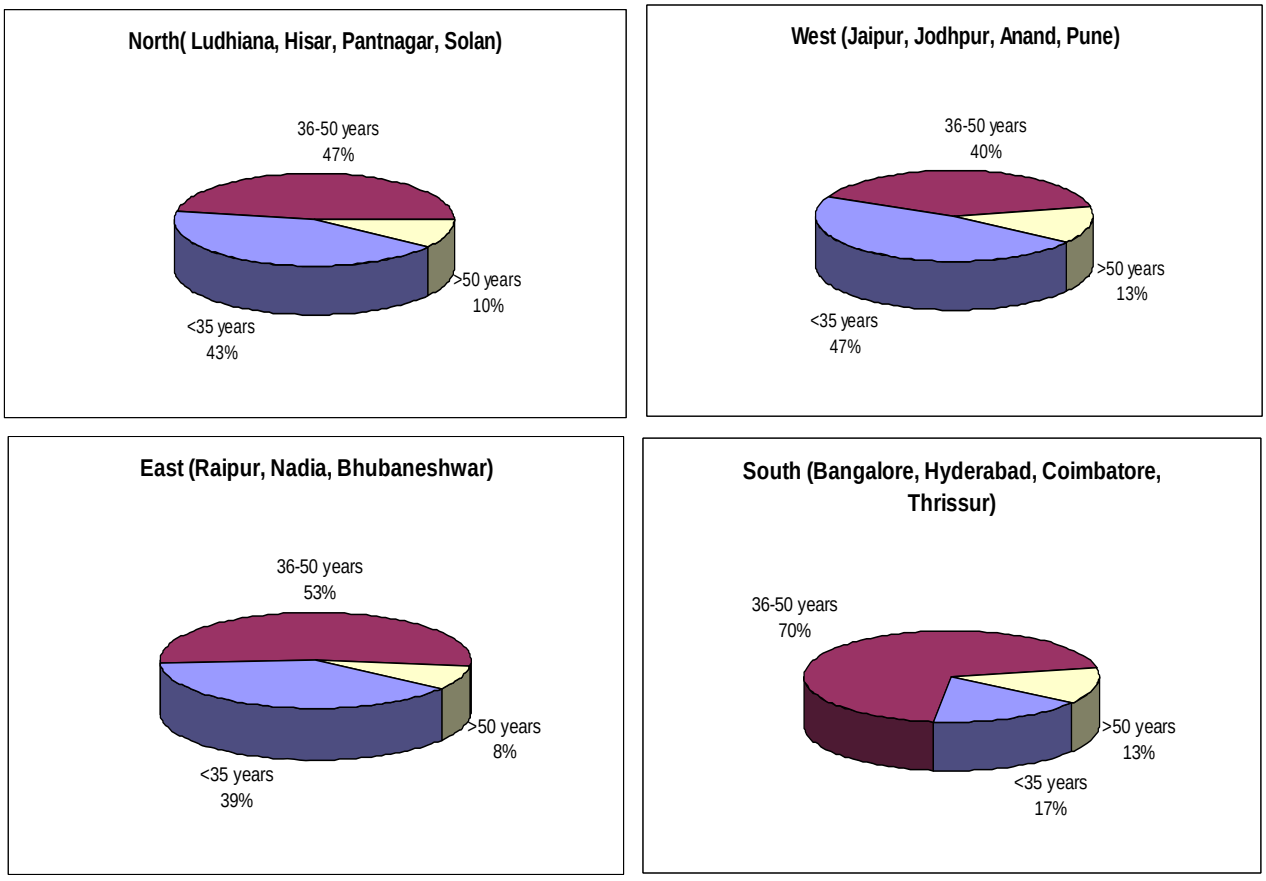

Fig 4.1 Pie Chart depicting the age group of farmers in different zones of the country

***(b) Educational level of farmers*:**

Figure 4.2 shows the education level of farmer in the four zones of the country. **T**he pie graph depicts that 52% of the farmers in North and west are at least matriculate followed by east (48%) and south with 45%. Although the percentage of illiterate farmers is very less about 0-8%, it is maximum in east and nil in the west. Interestingly about 6-17% of the farmers are college pass with west leading in this category

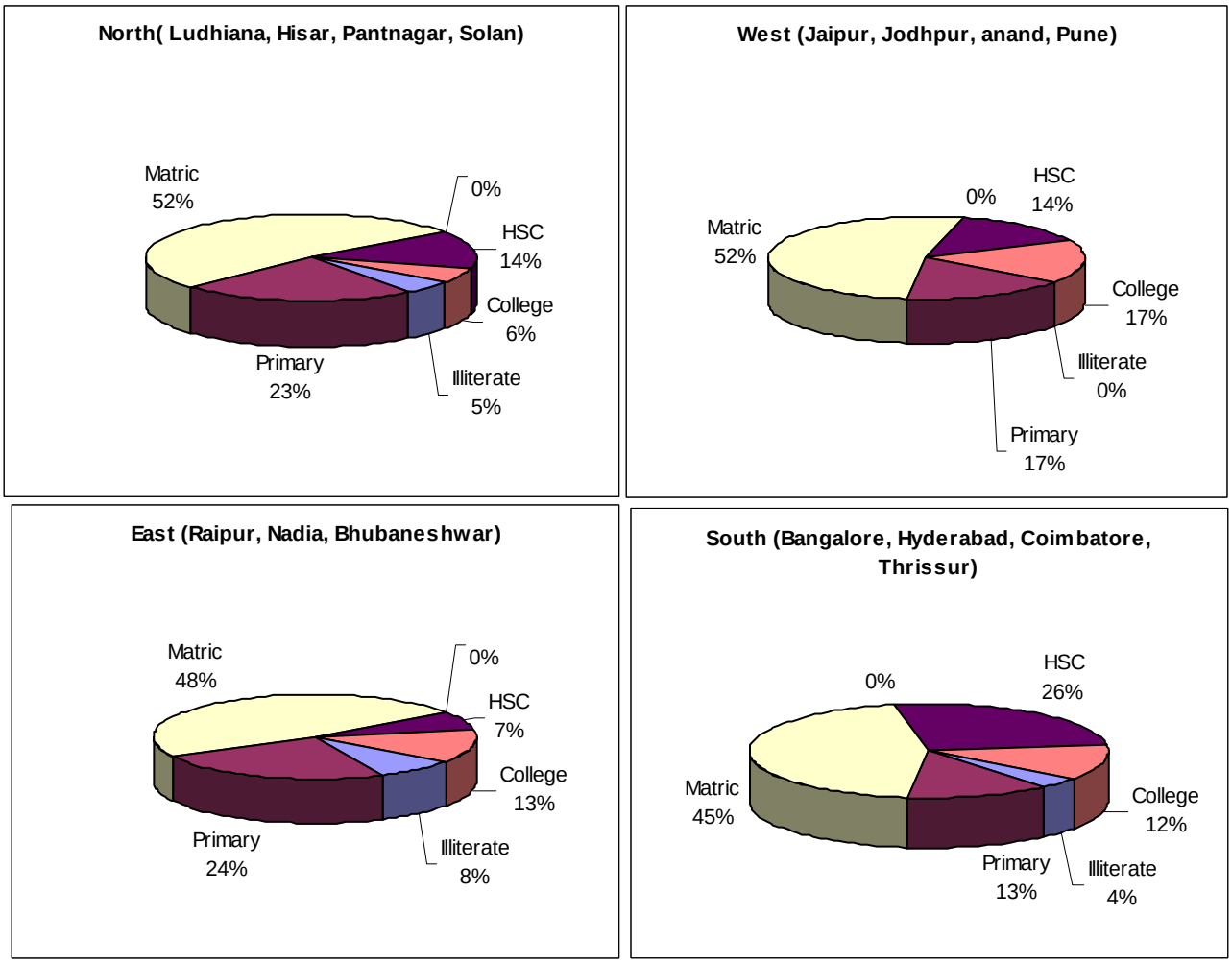

Fig 4.2 Pie Chart depicting the educational level of farmers in different zones of the country

(c) Size of holding

The pie graph in Figure 4.3 depicts the size of land holdings of the farmers in the 4 zones. It is seen that in general farmers in the west have large land holdings where 12% of the farmers have land holdings greater than 25 acres followed by 40% in the 10-25 acres category. The west zone is followed by stations in the north where 23% farmers have land holdings greater than 10 acres; 26% have land in the 5-10 acres and rest 51% have holdings of less than 5 acres. In the east and southern zone the farmers generally have small to medium land holdings ranging between 2.5-5 acres (east-65%; south-71%).

22% of the farmers in the east and 6% in the south have land holdings greater than 10 acres.

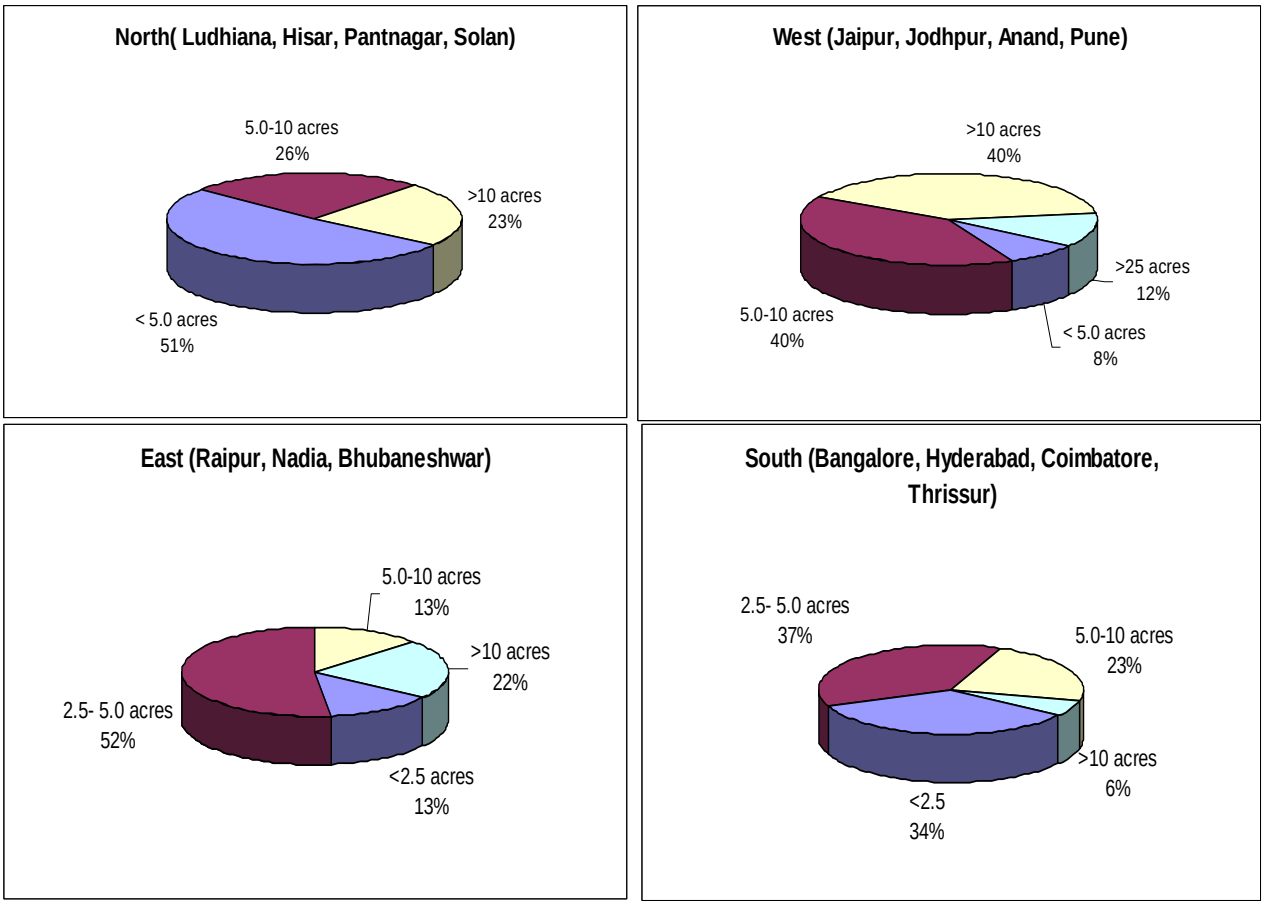

Fig 4.3 Pie Chart showing the land holdings owned by different farmers of the country

(d) Major crops grown by the selected farmers in the last 10 year

The following Table shows the major crops grown by the farmers in different regions of the country during different seasons. The crops grown basically depend on the soil type, cropping pattern, weather conditions and also whether the crops are irrigated or rain fed.

Table 4.1. Major crops gown in the 15 AAS units in Kharif and Rabi seasons

Station	Major Crops grown	Crops considered under the project
Anand	Paddy, Pearlmillet, Wheat, Gram**,** Mustard, Tobacco, Brinjal, Tomato, Chilly, Banana, Potato	Potato, Tobacco
Bangalore	Paddy, Maize, Sorghum, Ragi, Navane And Save; Redgram Field Bean, Horse Gram, Cowpea, Black Gram; Groundnut, Sunflower, Soyabean; Vegetables: Tomato, Brinjal, Chilli, Cauliflower, Cabbage, Cucumber, Potato, Onion, Grapes, Mango, Banana, Sapota, Guava; Coconut, Cashew Nut	Ragi, Redgram

Bhubaneshwar	Rice, Greengram, Black gram, Groundnut, Coconut, Cashewnut, Pointed Gourd, Tomato, Brinjal, Okra	Rice (direct sown & transplanted),Tomato
Hisar	Cotton, Bajra, Jowar, Guar, Moong, Cowpea, Moth, Sugarcane, Mustard, Wheat, Barley, Gram Lentil, Methi, Carrot ,Radish, Cauliflower	Cotton, Mustard
Hyderabad	Rice, Jowar, Maize, Pigeonpea, Greengram, Chickpea, Groundnut, Sunflower, Castor; Cotton, Tomato, Brinjal, Leafy Vegetables (Palak, Amaranthus, Etc.,) Carrot, Beet Root, Beans, Bhendi, Mango, Sapota, Citrus	Rice, Tomato, Palak, Cotton
Jaipur	Pearl Millet, Peanut, Cluster Bean, Green Gram, Moth Bean, Cowpea; Pumpkin, Bitter Gourds, Tomato, Brinjal, Okra, Chillies, Cluster Bean, Cucumber, Onion, Ridge Gourd, Bottle Gourd; Pearl Millet Fodder (In Irrigated Areas); Wheat, Chickpea (Gram), Barley And Mustard; Pea, Tomato, Brinjal, Cauliflower, Cabbage, Cucumber, Onion, Carrot, Radish, Garlic; Coriander, Cumin, Fenugreek, And Fennel, Ajwain; Lucerne; Ziad Green Gram Muskmelon, Watermelon, Cucurbits, Chillies, And Cluster Bean, Pearlmillet Fodder	Pearl Millet, Wheat, Gram
Jodhpur	Pearl Millet, Moong, Moth, Clusterbean, Sesame, Sorghum, Clusterbean, Groundnut, Cotton, Tomato, Chilly & Caster (Oil Seed), Mustard Wheat, Barely Cumin, Carrot, Chilly And Vegetables Crops	Pearl Millet, Mustard, Cumin
Kalyani	Rice, Wheat, Bengal Gram, Green Gram, Black Gram, Lentil, Mustard, Sesame, Linseed, Groundnut, Sunflower, Niger,Cabbage, Cauliflower, Bottle Gourd, Bitter Gourd, Ridge Gourd, Pointed Gourd, Chilli, Potato, French Bean, Brinjal, Cucumber, Radish, Bhindi, Knolkhol, Broad Bean, Beet, Carrot, Spinach, Amaranthus, Indian Spinach, Banana, Mango, Jack Fruit, Guava, Litchi, Pomogranate, Coconut, Areca Nut, Betel Vine, Ginger, Turmeric, Coriander, Onion, Fennel, Garlic, Jute, Sunflower, Rose, Chrysanthemum, Marigold, Jasmine	Rice (Boro & Aman), Jute, Mustard
Ludhiana	Rice, Wheat	Rice, Wheat
Pantnagar	Rice,Sugarcane, Maize, Soybean, Moong, Urd, Arhar, Groundnut, Seasonal Vegetable Crops,Wheat, Lentil, Gram, Pea, Rapeseed, Mustard,Potato, Seasonal Vegetable Crops Are Grown During Rabi Season. Urd, Moong And Sunflower Are Also Grown During Summer Season As Zaid Crops. Mango, Guava, Lemon And Leechi Are Main Fruit Crops	Rice, Wheat

Pune	Bajra, Sorghum And Wheat; Green Gram, Black Gram; Groundnut, Soybean, Sugarcane ,Onion, Cauliflower, Cabbage, Brinjal,Tomato, Okra, Potato, Leafy Vegetables, Guava, Kagdi Lime, Coconut	Wheat, Pearl millet, Onion
Raipur	Rice, Wheat, Maize, Jowar, Gram, Lathyrus, Lentil, Pigeon Pea, Green Gram, Black Gram, Soybean, Castor, Groundnut, Mustard, Sesame, Linseed, Cauliflower, Ivy Gourd, Ridge Gourd, Tomato, Chilli, Potato, Sem, Cowpea, Cucumber, Papaya, Banana, Mango, Guava, Custard Apple, Ginger, Coriander	Rice, Wheat, Gram
Solan	Tomato, Capsicum, French-Beans, Maize, Bitter Gourd, Seet Gourd, Pumpkin; Peach, Plum, Apricot, Pomegranate, Pear, Strawberry. Pea, Cabbage Family, Cauliflower, Garlic, Turmeric, Ginger, Leafy Vegetables (Methi, Palak, Dhania, Sarson, Salad, Lettuce, Wheat, Pulses , Oil Seed Crops, Maize Etc	Tomato, Capsicum, Peach, Apricot
Thrissur	Coconut, Arecanut, Banana, Black Pepper, Vanilla, Paddy, Vegetables, Nutmeg, Cashew, Rubber, Tapioca, Ginger	Coconut, Banana , Rice (irrigated & rainfed)

5. Survey results of economic impact of AAS (Quantity and Price)

The Project Scientists visited the selected farmers of both AAS and non-AAS categories on specified time schedules. These visits were planned in such a way so as to coincide with the dates of different operations like land preparation, sowing, planting, irrigation scheduling, fertilizer applications, harvesting and post-harvesting operations. The Nodal Officers carried out the survey based on the queries in the questionnaire designed by NCAP. This questionnaire includes the dates of all the operations, 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. Based on the data collected, the assessment of the impact of AAS in economic terms was carried out by the nodal officers with the help of NCMRWF

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. Given below are the detailed analysis of each crop undertaken by the 15 units. The results are based on the following aspects

- Impact of AAS on cost of cultivation
- Impact of AAS on net returns
- Impact of AAS on yield

Therefore the information given below for each crop broadly covers the following.

- AAS units undertaking study on specified crop
- General Information of the crop
- Weather Sensitive farm operations
- Weather sensitive crop growth stages
- Measuring the Impact of AAS
- Case Studies

- Overall analysis of the results obtained in terms of use of weather based AAS.

Most of the information is put in the form of Tables. These Tables are self-explanatory and do not need further elaboration.

(a)Cereals : Rice and wheat

- **Rice**
  - **AAS units undertaking study on rice**

Hyderabad	Season: Kharif & Rabi
Raipur	Season: Kharif
Thrissur	Season: Kharif & Rabi
Kalyani	Season: Kharif & Rabi
Bhubaneshwar	Season: Kharif & Rabi
Ludhiana	Season: Kharif
Pantnagar	Season: Kharif

  - **General Information of the crop**

Rice is grown under widely varying conditions of altitude and climate. Rice is considered to be warmth and humid loving crop. It requires prolonged sunshine and assured water supply. Rice accommodates itself under an annual rainfall ranging from 1000 mm to 1500 mm or even more. The atmospheric temperature has considerable effect on growth and development of rice plants. Rice needs relatively high temperature ranging between 25 to 35^0C for optimum growth and development of plants. However, high temperature, especially during nights, leads to greater respiration losses of the accumulated food materials. Therefore, for higher grain yield a day temperature of 25 to 33 ^{0}C and night temperature of 15 to 20 ^{0}C are preferable. A higher mean temperature ranging between 25 to 32 ^{0}C per day would reduce the growth duration and accelerate flowering. Whereas a mean temperature of less than 15^0C would cause a dormant stage or a slow vegetative growth but plants fail to flower. Rice crop prefer to have bright sunshine for an enhanced photosynthetic activity and higher yields. Bright days associated with gentle winds are the best condition because CO_2 supply and utilization are regulated to the maximum. Heavy wind causes severe lodging or shattering depending upon the crop growth stage. Rice is essentially a short day plant. A combination of temperatures, photo-period and light intensity, however, determines the growth period, growth rate, crop performance and productivity.

Rice is grown in both Rabi and Kharif season in Hyderabad. Yields in Rabi are higher than Kharif due to higher nitrogen use efficiency in view of abundant availability of solar radiation. In Thrissur also it is grown both in Rabi and Kharif season with Kharif paddy being rainfed. In Bhubaneshwar paddy is grown under both direct sown and transplanted condition. In Raipur, Ludhiana, Pantnagar it is taken up during Kharif season. In Kalyani in West Bengal, two varieties of paddy are grown namely Boro in Kharif and Aman in Rabi season.

  - **Weather Sensitive farm operations**

All farm operations are sensitive to paddy growth. They are: Sowing; Raising of seedlings ; Transplanting, Irrigation, Fertilizer application, Plant protection; Harvesting

- **Weather sensitive crop growth stages**

Crop		Crop growth stage	Std Met. Week *	Important weather parameter related to respective crop growth	Effect of weather parameter
Paddy (Long duration)	Hyderabad	Time of transplanting	26-31	Rainfall	Timely transplanting
		Tillering	30-34	Cloud cover, rainfall and temperature	Incidence of diseases and pests
		Panicle initiation	35-38	Cloud cover, rainfall and minimum temperature	Incidence of diseases and pests
		Flowering	36-39	Cloud cover, rainfall and minimum temperature	Incidence of diseases and pests
		Grain filling	37-40	Cloud cover, rainfall and minimum temperature	Incidence of diseases and pests
		Harvesting	40-45	Rainfall	Damage to grain
Paddy	Raipur	Emergence phase	25	Rainfall	Deficit or excess rainfall effect the emergence
		Seedling phase	26-28	Rainfall & Sunshine	Deficit rainfall increase the weed growth
		Transplanting phase	29	Rainfall	Deficit rainfall hampers the transplanting
		Tillering phase	30-33	Rainfall	Excess rainfall decreases the tiller production
		Vegetative lag phase	34-35	Cloudiness	Reduced biomass and photosynthesis
		Reproductive phase	36-38	Rainfall	Reduced pollination
		Grain ripening phase	39-42	Sunshine	Increases fertile spikelets

Paddy	Thrissur Kharif	Sowing	19 – 21st week (May 7-27)	Lack of pre-monsoon showers or heavy rainfall after sowing	Lack of pre-monsoon showers affect the sowing process and further it will affect the timely sowing of second season crop. Heavy pre-monsoon rainfall after sowing / transplanting causes washing away of seedlings.
		Flowering	28-31st week (July 9-August 5)	Rainfall	Wet spell during flowering period in *kharif* are detrimental. 20 per cent loss is expected due to grain chaffing.
		Harvesting	35-37th week (August 27-September 16)	Rainfall	Rainfall during harvest stage will affect the harvesting operation and cause yield loss, grain quality
	Rabi	Sowing / transplanting	38 - 41st week (17th September – 14th October)	Rainfall	Heavy rainfall during this period will cause delay in sowing/transplanting which in turn affect the crop yield by exposure of crop during dry spell period.
		Reproductive stage	45-46th week(5th November–18th November	Early cessation of northeast monsoon rainfall	Dry spell during this period will affect the production
Paddy	Kalyani Boro	Seedling	3-4 Met wk	Severe cold ,rain	Yellowing of leaves
		Tillering to flowering	6-10 Met. Week	Rain and cloudiness	Sheath blight, Brown spot

	Bhubaneshwar Timely sown (transplanted)	Vegetative Flowering Maturity stage Harvesting	6-8th week (5th –25th Feb) 12th-13th week (19th Mar-1st pr) 16-29th April	Low temperature Wind speed Cloud cover Cloud cover	Retarded vegetative growth Imperious effect on pollination Set back in grain filling (owing to less energy out put) Difficulty in sun drying
	Late sown (transplanted	-	30th April-6th May	-	-
Paddy	Ludhiana	Seedling	22	Rainfall	Seedling mortality & less growth at lesser rainfall
		Transplanting	26	High temperature	High temperature is harmful
		Tillering stage	28	Temperature	Increased temperature less tillering, effected by low night temperature
		Panicle initiation stage	31	High wind speed	High wind speed desiccate panicles
		Booting stage	35	High temperature and High humidity	High temperature less elongation, susceptible to rainfall
		Heading stage	36	High temperature	Very sensitive to high temperature
		Flowering stage	38	High temperature and strong winds	High temp. causes anthesis sterility, strong winds shreds flowers
		Milky stage	39	Temperature	Low night temperature
		Dough stage	40		
		Maturation stages	42	Rainfall and strong winds	Causes Lodging

Paddy	Pantnagar	Transplanting	24 to 29	Rainfall	More area is covered for transplanting if sufficient rainfall
		Tillering	26 to 31	Rainfall & Temperature	More tillers
		Grain filling	40 to 41	Temperature	Less grain if temp. is low
		Harvesting	42 to 43	Rainfall & Wind	Harvesting & Threshing Delayed

* For Standard Meteorological Week see Annexure-II

- **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation (Rs/acre)	Impact of AAS on gross returns (Rs/acre)	Impact of AAS on net returns (Rs/acre)	Impact of AAS on yield (Q/acre)
Raipur	Paddy	Decrease by 12.3%	Increase by 12.0%	Increase by 55.8%	Increase by 10.3%
Thrissur	Paddy-Kharif	Decrease by 5.6%	Increase by 7.5%	Increase by 11.5%	Increase by 7.6%
Thrissur	Paddy- Rabi	Decrease by 5.6%	Increase by 12.1%	Increase by 19.2%	Increase by 12.4%
Kalyani	Boro Rice	Decrease by 13.4%	Increase by 8.3%	Increase by 24.7%	Increase by 18.1%
Kalyani	Aman Rice	Decrease by 11.2%	Increase by 23%	Increase by 21%	Increase by 14.2%
Bhubaneshwar	Transplanted Rice	Increase by 8.5%	Increase by 11.3%	Increase by 16.1%	Increase by 12.0%
Ludhiana	Rice	Decrease by 7.7%	Increase by 8.6%	Increase by 21.2%	Increase by 8.8%
Hyderabad	Paddy	Decrease by 13.24%	Increase by 8.1%	Increase by 27 %	Increase by 0.4%
Pantnagar	Paddy	Decrease by 5%	Increase by 8.1%	Increase by 19.1%	Increase by 21.3%

- **Case Studies**

Station	Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation (write the recommendation also)	Whether AAS Recommendation followed	What is the loss/gain achieved due to the recommendation (AAS vs non AAS)	
							In Total cost of cultivation (Rs/ac)	In Net returns (Rs/ac)
Raipur	Kharif 04	Paddy	Beushening	Rainfall	July 16, 2004 Bueshning operation can immediately be done	Followed	The AAS farmers benefited over the non-AAS farmers by following the recommendations.	
	Kharif 04	Paddy	Tillering	Rainfall	August 24, 04 Spraying of fungicide is recommended	Followed		
		Paddy	Biasi	Rainfall	July 26, 05 Moderate rain expected. Farmers can go for Biasi operation	Followed		
	Kharif 05	Paddy	Interculture and Plant protection	Rainfall	August 30, 05 Clear weather, farmers can go for plant protection and interculture operation	Followed		
Thrissur	*Rabi* 03-04	Paddy	Spraying	High relative humidity and low temperature	October 14, 2003 **Recommendation:** Infestation of leaf folder is seen in paddy, use a thorny stick and open the folded leaves, spray Monocrotophos/ Quinalphos/carbaryl in the infested zone of the field.	All the farmers followed	Marginal insignificant increase only (19/-)	1173
	Kharif 06	Paddy	Spraying	Cloudy weather, high relative humidity and low temperature	June 13 & 27 and July 4, 2006 **Recommendation:** Infestation of leaf folder is seen in paddy, use a thorny stick and open the folded leaves, spray Monocrotophos/Quinalphos/carbary	43 per cent of farmers followed	367	850

	Rabi 06-07	Paddy	Spraying	Daily average temperature of 27 - 28°C and high relative humidity	November 21 &28 and December 5&12, 2006 **Recommendation:** Rice bug infestation is noticed in paddy. Dust Metacid or spray Carbaryl, Malathion or Metacid	27 per cent of farmers followed	631	1345
Bhubaneshwar	Kharif 04	Rice (Transplanted)	Fertilizer and pesticide application	Rainfall and temperature	August 2004	Followed	1455	2320
		Rice (Direct seeded)	Herbicide application	Rainfall	September 2004	Followed	188 less	1452
	Kharif 06	Rice (Transplanted)	Fertilizer and pesticide application In Nursery and main field	Rainfall and temperature	August 2006	Followed	1376	1968
		Rice (Direct seeded)	Herbicide and pesticide application	Rainfall		Followed	786	1204
Hyderabad	Kharif - 04	Paddy	Pesticides application	Cloud cover, Rainfall	Dt. October 5 2004 (Tricyclazole)	Yes	Rs. 553 (7.4 %)	Rs. 771 (12.55%)
	Kharif 05	Paddy	Pesticides spraying	Cloud cover, Night Temp	Dt. October 25 2005, (Edifenphos)	Yes	Rs. 1239 (17%)	Rs. 1340 (19%)
	Kharif - 06	Paddy	Pesticides spraying	Temperatures	Dt. October 17 2006 (Acephate)	Yes	Rs. 1022 (15.43%)	Rs. 1764 (23.74%)
Ludhiana	Kharif 2004	Paddy	Transplanting	10-06.2004 Dry weather	Start transplanting of rice, apply recommended dose of fertilizers and for weed control use butachlor or Anilophos in the standing water within 2-3 days after transplanting	Followed	Saved the crop from weed	
	Kharif 2005	Paddy	Irrigation	05.07.2005 Mainly cloudy weather with moderate to heavy rainfall	As rainfall is expected in coming days. The farmers advised to save irrigation water by not applying irrigation.	Followed	Rs 200 per acre	

	Kharif 2006	Paddy	Irrigation	01.08.2006 Generally cloudy weather is expected	Irrigation to rice crop may be applied two days after the ponded water has infiltrated into the soil but rice fields should not be allowed to develop cracks. Last dose of nitrogen through 35 Kg urea may be applied, if already not given.	Followed	
	Kharif 2006	Paddy	Plant Protection	11.08.2006 Partly cloudy weather expected	For the control of Plant hopper, Leaf folder and stem borer, spray the crop with recommended pesticides on clear days	Followed	Rs 250 per acre

- **Overall analysis of the results obtained in terms of use of weather based AAS.**

Station: Bhubaneshwar

Input	**Amount of Input used in (Rs/acre)**		**Difference in yield due to the input (Rs/Acre)**			**Difference in the cost of cultivation(Rs./acre)**		
Transplanted Rice	**AAS**	**Non-AAS**	**AAS**	**Non-AAS**	**Difference**	**AAS**	**Non-AAS**	**Difference**
Seed	180	218	11770	10505	1265	7280	6410	870
Fertilizer	857	658						
FYM	804	573						
Irrigation	318	88						
Herbicide	73	20						
Pesticide	619	409						
Human labour	2882	2652						
Bullock labour	168	314						
Machine labour	1133	1099						
Assoc. cost	246	379						

Station : Raipur

Input (per acre)	Amount of Input used		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (kg/acre)	21	24	23.6	21.4	2.2	7197	8210	-1013
Fertilizer (kg/acre)	162	171						
Pesticide(kg/acre)	0	0						
Pesticide(l/acre)	0	0						
Human labour (Mandays/acre)	31	35						
Machine labour (Total hours/acre)	5	5						
Irrigation (no.) (per farmer)	1	2						

Station : Thrissur

Input	Amount of Input used (kg/ha)		Difference in yield due to the input (Q/ha)			Difference in the cost of Cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non- AAS	Difference	AAS	Non- AAS	Difference
Kharif season								
Seed	126	135	27.5	25.5	2.0	6976	7379	-403
Fertilizer	360	374						
FYM	927	911						
Irrigation	N/A	N/A						
Plant protection chemical								
Herbicide	-	-						
Pesticide	0.23	0.20						
Rabi season								
Seed	120	134	32.8	28.7	4.1	7748	8210	-462
Fertilizer	578	465						
FYM	1060	921						
Irrigation	-	-						
Plant protection chemical								
Herbicide	-	-						
Pesticide	0.5	0.4						

Station: Kalyani

Input	Amount of Input used		Difference in yield due to the input			Difference in the cost of cultivation(Rs/acre)		
Boro Rice	**AAS**	**Non-AAS**	**AAS (Q/acre)**	**Non-AAS(Q/Acre)**	**Difference (Q/acre)**	**AAS**	**Non-AAS**	**Difference**
Seed (Kg/acre)	31.4	32.0	49.3	41.7	7.6	7614	8795	-1181
Fertilizer (Kg/acre)	87	101						
FYM	0	0						
Irrigation (no./acre)	5	5						
Plant protection chemical	0	0						
Herbicide	0	0						
Pesticide (lts./acre)	0.03	0.31						
Etc.. ..(land prep…..)								
Aman Rice								
Seed (Kg/acre)	27	29	43.8	38.3	5.4	6266	7059	-793
Fertilizer (Kg/acre)	73	92						
FYM	0	0						
Irrigation (no./acre)	1	1						
Plant protection chemical	0	0						
Herbicide	0	0						
Pesticide (lts./acre)	0.1	0.2						

Station: Ludhiana

Input	Amount of Input used In (kg/acre)		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation In (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (kg per acre)	8	8	27.3	25.1	2.2	6186	6705	-519
Fertilizer(kg/acre	143	152						
Herbicide (kg/acre)	1	1						
Pesticide(kg/acre)	1	0						
Human labour Mandays/acre)	17	21						
Machine labour (Total hours/acre)	62	75						
Irrigation (no.) (per farmer)	16	19						

Station: Pantnagar

Input	Amount of input used		Difference in yield due to input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seed (kg/acre)	14	15	23.3	19.2	4.1	5087	5356	-269
Fertilizer kg/acre)	129	124						
Herbicide (kg/acre)	1	1						
Pesticide kg/acre)	6	7						
Human labour (mandays/acre)	26	18						
Machine labour (hrs/acre)	9	7						
Irrigation (no/acre)	6	7						

Station: Hyderabad

Input	Amount of input used		Difference in yield due to input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seed (kg/acre)	61	68	142	141	1.0	18447	21262	-2815
Fertilizer kg/acre)	246	313						
Pesticide kg/acre)	2	7						
Human labour (mandays/acre)	30	39						
Machine labour (hrs/acre)	4	5						
Irrigation (no/acre)	5	4						

- **Wheat**

  - **AAS units undertaking study on wheat**

    Raipur Season: Rabi
    Ludhiana Season: Rabi
    Pantnagar Season: Rabi
    Jaipur Season: Rabi
    Pune Season: Rabi

  - **General Information of the crop**

The ideal weather condition for wheat cultivation is cool, moist weather during the major portion of the growing period followed by dry warm weather to enable the grain to ripen properly. Warm temperature at this stage is unfavourable to tillering and also promotes several diseases. Too much of rain during the season results in heavy incidence of rusts. For vegetative growth crop requires 15 to 20°C. High temperature during the rapid growth results in poor tillering, low number of effective tillers, poor growth rate, low LAI, short ears with lower number of spikelets, lower grain weight and lower quality. It is highly sensitive to moisture stress during the period from shooting to advance heading stage. Optimum rainfall requirement is 50-87.5 cm during the growing season and the water requirement is 35-55 cm for different varieties and seasonal condition.

  - **Weather sensitive farm operation:**

Sowing, Irrigation, Plant protection (wed control), Harvesting & Threshing, and post harvest are some of the main weather farm operations. The other specific stage wise weather farm operations are Crown root initiation stage (21 days from sowing);Tillering stage (42 days from sowing); Flowering stage (63 days from sowing); Milk stage(84 days from sowing); Dough stage (105 days from sowing)

  - **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation (Rs/acre)	Impact of AAS on gross returns (Rs/acre)	Impact of AAS on net returns (Rs/acre)	Impact of AAS on yield (Q/acre)
Raipur	Wheat	Increase by 3.1%	Increase by 10.0%	Increase by 13.1%	Increase by 7.5%
Ludhiana	Wheat	Increase by 2.6%	Increase by 12.9%	Increase by 19.3%	Increase by 9.6%
Jaipur	Wheat	Decrease by 0.70 %	Increase by 8.84 %	Increase by 14.36 %	Increase by 5.71 %
Pune	Wheat	Increase by 4.0%	Increase by 13.3%	Increase by 28.5%	Increase by 32.5%
Pantnagar	Wheat	Decrease by 8.1%	Increase by 7.5%	Increase by 12.3%	Increase by 17.9%

- **Weather sensitive crop growth stages**

Crop		Crop growth stage	Standard Met. Week *	Important weather parameter related to respective crop growth	Effect of weather parameter
Wheat	Raipur (Timely Sown	Anthesis	4 – 8	Rainfall	Pollination affected
				High temperature	Sterility and stunted growth
		Harvesting	12 – 15	Rainfall	Lodging
		Anthesis	4 – 8	Rainfall	Pollination affected
				High temperature	Sterility and stunted growth
	Late Sown	Harvesting	12 – 15	Rainfall and wind speed	Lodging
Wheat	Ludhiana	Crown root initiation stage	48	Rainfall	Rainfall is beneficial for crop growth
		Jointing	50	High temperature	High temperature is harmful
		Flowering	3	Rainfall	Rainfall is beneficial for crop growth
		Milking	11	High wind speed	High wind speed is harmful for the crop
		Grain Development	13	High temperature and High humidity	High temperature and high humidity are harmful to the crop and reduces the yield of crop
		Maturity	14	High wind speed	High wind speed is harmful for crop yield
Wheat	Pantnagar	Early sown	45-46	Rainfall & Temp..	Germination & tillering
		Med. Sown	47-51	Rainfall & Temp.	Germination, tillering & flowering
		Late sown	52-02	Rainfall, Temp. & Wind	Germination, tillering, flowering & Yield
		CRI	49 - 04	Rainfall	Highly critical and sensitive to water
		Tillering	52-08	Minimum temp.	More tiller under low temperature
		Ear head emergence	09 to 12	Both Max & Mini. Temp. 7 Wind speed	Grain filling, lodging with irrigation /rainfall under high winds

Wheat	Jaipur	Sowing	46	Temperature	Reduce germination
		Crown root initiation stage	49	Moisture	Reduced yield by 15-20% if irrigation is not given
		Tillering	52	Temperature	High temperature reduce tillering
		Early emergence	96	Cloudy weather	Cause aphid attack & rust disease
		Milk stage	9	Temperature	High temperature cause shriveling of grains and reduce grain weight.
Wheat	Pune (early sown)	CRI	43	Temperature maximum	Effect & weather parameter
		Tillering	46	Temperature minimum	Warm temperature enhance germination
		Flowering	50	Temperature minimum	Cool temp. up to 10^0C & humidity above 85% increase tillering
		Milk stage	1	Temperature minimum	Cool temperature up to 8^0C with less range of in diurnal temperature
		Physiological maturity	5	Temperature	Cool temperature with less range of diurnal temperature
	Timely sown	CRI	45	Temperature maximum	Warm temperature enhance germination
		Tillering	48	Temperature minimum	Cool temp. up to 10^0C & humidity above 85% increase tillering
		Flowering	51	Temperature minimum	Cool temperature up to 8^0C with less range of in diurnal temperature
		Milk stage	3	Temperature minimum	Cool temperature with less range of diurnal temperature
		Physiological maturity	8	Temperature	Cool temperature with less rang of diurnal temperature.

* For Standard Meteorological Week see Annexure-II

- **Case Studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS recommendation followed	Gain/loss due to the recommendation (AAS vs Non AAS)
Rabi04-05	Wheat Pune	Plant protection	Temperature minimum	Jan 25 2005, Feb 2 2005 The rust on wheat should be controlled by spraying of Dithane Z-78, 1250 g. in 500 liter water + 2% Urea should be done per hectare. If there is attack of insect pest mix 500 ml Monocrotophos in above solution.	Recommendation followed	By following the recommendation, yield loss due to unfavourable weather was kept in check. In all the AAS farmers had a 12% increase in yield over the non-AAS farmers
Rabi-05-06		Sowing	Temperature minimum	Oct 18 2005 Sowing of irrigated wheat should be done during 15th October to 15th November Oct 25 2005 There is a prediction of low minimum temperature, which is favorable for sowing of wheat	Recommendation followed	
		Irrigation	Temperature minimum	Jan 31 2006Wheat crop is in milking stage, irrigate wheat in this stage. Irrigation should be given according to the stage of wheat crop	Recommendation followed	
Rabi06-07		Harvesting	Temperature	Feb 2 2007 Complete the harvesting paradise at morning, which get the benefit of humid climate resulting into reduce of loss due to shedding of grain from ear head.	Recommendation followed	
Rabi 03-04	Wheat Ludhiana	Sowing	Dry weather	Oct 30 2003: Optimum time for the sowing of wheat and treat the seed with vitavax	Followed	The yield of Wheat crop increased by
Rabi 04-05		Irrigation	Dry weather	Jan 6 2005: Apply second irrigation to the wheat crop and first irrigation to late sown and remaining dose of nitrogen fertilizer to normal as well as late sown wheat		
Rabi 05-06		Harvesting	Dry Weather	Apr 18 2006. It is optimum time for the harvesting of wheat crop		
Rabi 04-05	Raipur	Milking stage	Rainfall	Feb. 01, 2005. Rainfall is useful for the wheat crop, farmers were recommended for top dressing.	Followed	The yield of Wheat crop increased by
Rabi 05-06		Harvesting	Rainfall	March 31, 2006 Clear weather farmers can go for harvesting		
Rabi06-07		CRI Branching	Temperature	Jan 02, 2007 Irrigation was recommended for both the crop		

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Station: Raipur

Input (per acre)	Amount of Input used (Kg/acre)		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (kg/acre)	37	38	14.0	13.0	1.0	3812	3699	113
Fertilizer(kg/acre	76	86						
Herbicide (kg/acre)	0	0						
Pesticide(kg/acre)	1	44						
Human labour (Mandays/acre)	6	7						
Machine labour (Total hours/acre)	5	6						
Irrigation (no.) (per farmer)	5	5						

Station: Ludhiana

Input	Amount of Input used In (kg/acre)		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (kg per acre)	40	40	35.5	32.4	3.1	5262	5130	132
Fertilizer(kg/acre	150	153						
Herbicide (kg/acre)	147	131						
Pesticide(kg/acre)	150	0						
Human labour (Mandays/acre)	7	7						
Machine labour (Total hours/acre)	14	15						
Irrigation (no.) (per farmer)	0	0						

Station: Jaipur

Input	Amount of Input used In (kg/acre)		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (kg per acre)	40	43	26.7	24.8	1.9	5207	5803	-596
Fertilizer(kg/acre	114	101						
Herbicide (kg/acre)	0	0						
Pesticide(kg/acre)	26	15						
Human labour (Mandays/acre)	29	35						
Machine labour (Total hours/acre)	9	10						
Irrigation (no.) (per farmer)	6	7						

Station: Pantnagar

Input	Amount of input used (kg/acre)		Difference in yield due to input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seed (kg/acre)	30.1	30.3	63.7	54	9.7	3206	3488	-282
Fertilizer (kg/acre)	50	80						
Pesticide (kg/acre)	0	1						
Human labour (man days/acre)	2	3						
Machine labour (hrs/acre)	5	4						
Irrigation (no/acre)	2	3						

(b) Millets : Finger Millet & Pearl Millet

- **Finger Millet/Ragi**

  - **AAS units undertaking study on Finger Millet/Ragi**
    Bangalore Season: Kharif
  - **General information of crop**

Finger millet (*Eleusine coracana L. Gaertn)* is cultivated mainly in Asia and Africa. It is known by different names such as bird's foot or coracana in English, Ragi or Nangli. It is predominantly grown as a dry land crop in the peninsular Indian States of Karnataka, Andhra Pradesh and Tamil Nadu.

Crop like finger millet is well to known to respond to change in the climatic condition due to their adoptability, susceptibility to moisture stress, high relative humidity and high rainfall, however, physiology of finger millet can not respond all time change in the climatic condition. In India there are two main crop seasons of Ragi. The higher rainfall zones allowing sowing with early varieties. It is known as gidda Ragi sown during May in order to harvest the crop by September or October. Most areas are sown to late varieties (Hain or Dodda Ragi) between July and August, in order to harvest the crop by November or December or January. Irrigated Ragi is also sown in India. If irrigated, it is primarily a dry or a summer season crop grown between February and May on red sandy loams. Principal soil types on which finger millet is grown are red lateritic loams or sandy loams, where deficiencies of major nutrients are common. Temperature during the crop season varies between 25˚ and 32˚C, and a crop season might receive nearly 400 to 500 mm precipitation. It possesses good drought recovery characteristics, hence is suited for dry land agriculture, characterized by intermittent drought stress. Drought years will obviously provide much less water for the crop. Preferred altitude range for Ragi is between 1000 and 1800 msl.

- **Weather sensitive farm operation**

The weather sensitive farm operation is inter-cultivations, weeding and harvesting.

- **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Bangalore	Finger millet	Decrease by 8.3%	Increase by 10.4%	Increase by 45.9%	Increase by 10.4%

- **Weather sensitive crop growth stages**

Crop		Crop growth stage	Std Met. Week*	Important weather parameter related to respective crop growth stage	Effect of weather parameter
Ragi/ Finger Millet	**Bangalore Early sown** (transplanted)	Harvesting	12	Rainfall	Lodging and shedding of grains
	Timely sown (transplanted)	Vegetative & Panicle initiation stage	14	Rainfall and RH	Leads poor panicle development & grain filling
	Late sown (transplanted)	Grain filling (Maturity)	16	Rainfall	Poor grain filling leads lesser yields

* For Standard Meteorological Week see Annexure-II

- **Case Studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS Recommendation followed	What is the loss/gain achieved due to the recommendation (AAS vs. non AAS)	
						In Total cost of cultivation	In Net returns
Kharif 2005	Finger millet Bangalore	Inter cultivation and harvesting	Rainfall	December 12, 13, 14, 15 and 18 – 21 Sep 2005 Recon : No rain is forecasted; go for Inter cultivation and harvesting the crop	Yes	433 / ac	1290 /ac

- **Overall analysis of the results obtained in terms of use of weather based AAS.**

Input	Amount of Input used In (Rs/acre)		Difference in yield due to the Input in (Rs/acre)			Difference in the cost of Cultivation in (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed	87	103	7673	6950	723	4181	4557	-376
FYM	978	1079						
Fertilizer	572	600						
Human labour	1251	1512						
Bullock labour	300	268						
Machine labour	992	995						

- **Pearl Millet/ Bajra**

  - **AAS units undertaking study on Pearl Millet/ Bajra**

    Jodhpur Season: Kharif
    Jaipur Season: Kharif
    Pune Season: Kharif

  - **General information of crop**

Pearl millet is most important rainfed crop of this zone. This crops is largely cultivated by the farmers for both grain & fodder production. It responds to life saving irrigation under moisture stress conditions. It prefers hot & humid weather. Optimum time of sowing is first fortnight of July. Late sowing in the month of August causes poor stand of crop due to high rate of mortality of the seedlings, restricted vegetative growth, poor grain setting and more incidence of disease due to comparatively low temperature during the period.

  - **Weather sensitive farm operations:**

Sowing, plant protection, weed control, fertilizer application, harvesting & threshing and post harvest are some of the weather sensitive farm operations. Tillering and vegetative phase, flowering and grain formation stage are other operation

  - **Weather sensitive crop growth stages**

Crop	Station	Crop growth stage	Std. Met. Week*	Effect of weather parameters
Pearl Millet	Jaipur	Tillering	29	Water logging or moisture stress reduce tillering
		Ear emergence	33	High humidity & drizzling causes ergot
		Grain filling	36	Moisture stress causes shriveling of grains
	Jodhpur	Early sown	23rd to 25th	Pearl millet is sown with onset of monsoon after receiving sufficient rainfall. If rainfall does occurs at emerging stage, it causes crust formation and reduce the emergence percentage or plant population. Crop requires rainfall at seedling stage for survival
	Normal sown	Normal sown	26th to 28th	Normal sowing after receiving good rain and after sowing light rainfall occurs crust formation of top soil takes place. The crop yields depend on timely rainfall.
		Late sown	29th to 31st	In late sown crop, yield reduces due to less or no rainfall at the time of maturity caused by shortening of growing season due to moisture stress.

* For Standard Meteorological Week see Annexure-II

  - **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Jodhpur	Pearlmillet	Increase by 21.9%	Increase by 14.9 %	Increase by 10.9 %	Increase by 5.71 %
Jaipur	Pearl millet	Decrease by 1.05 %	Increase by 3.40 %	Increase by 10.74 %	Increase by 4.00 %
Pune	Pearlmillet	Increase by 2.0%	Increase by 9.4%	Increase by 28.9%	Increase by 26.8%

- **Case studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS Recommended action followed	What is the loss/gain achieved due to the recommendation (AAS vs non-AAS)	
						In total cost of cultivation(Rs/acre)	In Net returns (Rs/acre)
Kharif 04	Pearl millet Jodhpur	Intercultural like hoeing, weeding broad casting of N-fertilizers.	Rainfall	20thJuly to End 15th August With sufficient rainfall start hoeing and weeding and broadcasted urea.	yes	Rs 600/-	Rs. 800/-
Kharif-04	Pearl millet Jaipur	Fertilizer Application	Rainfall	31st Aug., 2004 . Forecast of no rain Top dressing of urea is suggested in view of dry weather	Yes	Light rains occurred Top dressed fertilizer wasted, loss of Rs 114.6 Per acre	Negative impact on net returns
Kharif 05	Pearl millet	Irrigation	Rainfall	End of August to September .	Yes	Rs. 360/-	Rs. 800
Kharif 2004	Pearl Millet Pune	Interculture	Rainfall	Jul 6 2004, Jul 27 2004 The sky will be cloudy Carry out interculture operations in already sown crops, especially hoeing, weeding	Yes	The AAS farmers received a yield of 12-15% more compared to the non-AAS farmers by following the recommendation	
Kharif 2005	Pearl Millet Pune	Harvesting	Rainfall	Sep 14 2004, Sep 17 2004 The sky will be partly cloudy. The harvesting of bajra, and groundnut should be done at maturity as there is favorable weather for harvesting.	Yes		
Kharif-06	Pearl Millet Pune	Sowing	Temp., rainfall	May 23 2006-Thisyear according to forecast there will be timely onset and good rainfall will occur. So it is advised to sow pulse crops.	Yes		
Kharif 2006	Pearl millet Pune	Interculture	rainfall	Looking into the forecast of rains farmers are advised to defer hoeing and weeding (29th July, 2006)	Followed	Saving of human labour, thus saving in cost of cultivation by Rs 161.0/acre	Contributed 49.8 percent to the net saving over non AAS
Kharif 2007	Pearl millet	Top dressing of fertilizer	Top dressing of fertilizer	Forecast of rains and farmers were advised not to top dress urea (27th July, 2007)	Followed	Saving in cost of cultivation by Rs 320/-	Saving in net returns over non AAS farmers by Rs 495/-

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Station: Jaipur

Input	Amount of Input used In (kg/acre)		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (kg per acre)	1.4	1.5	21.4	20.5	0.9	265	268	-3
Fertilizer(kg/acre	70	65						
Herbicide (kg/acre)	0	0						
Pesticide(kg/acre)	0.2	0						
Human labour (Mandays/acre)	9	10						
Machine labour (Total hours/acre)	4.3	5.1						

Station: Pune

Input	Amount of input used (kg/acre)		Difference in yield due to input (Q/acre)	Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	Difference	AAS	Non AAS	Diff
Seed (kg/acre)	1.3	1.4	26.8	3825	3750	75
Fertilizer (kg/acre)	95	79				
Human lab (mandays/acre)	34	30				
Machine labour(hrs/acre)	12	11				
Irrigation (no/acre)	0.7	0.1				

(c) Vegetables : Palak, Tomato, Capsicum,Onion,Potato

- **Palak**
  - **AAS units undertaking study on Palak**

    Hyderabad Season: Rabi

  - **General information of crop**

Palak is a cool season crop requiring mild climate. It tolerates frost and high temperature under good irrigation. Under high temperature conditions, early bolting occurs and leaves pass through edible stage quickly with poor yield. Well fertile sandy loam soils with good drainage is ideal. For good vegetative growth and yield, application of nitrogen @ 20-25 kg/ha, after every cutting as top dressing is recommended. Pre sowing irrigation and a light irrigation few days after sowing for better germination is ideal. In winter season, irrigation is required at 10-15 days interval. Its first flush of leaves become ready for cutting 3-4 weeks after sowing and subsequent cuttings are taken up at 15-20 days interval, thus 6-8 cuttings can be taken. Generally winter crop gives higher yield. An average yield of 8-12 t/ha of leaves can be obtained. The crop is prone to insect pests like aphids and diseases like leaf spots. The triggering events for the above pest and diseases are cloudy and wet weather.

  - **Weather sensitive farm operation**

Sowing; Irrigation, Plant protection; Fertilizer application and Harvesting

  - **Weather sensitive crop growth stages**

Crop	Crop growth stage	Standard Met. Week *	Important weather parameter related to respective crop growth stage	Effect of weather parameter
Palak	Sowing	40	Rainfall	For sowing timely
	Vegetative stage	42-12	Rainfall and cloud cover	Incidence of leaf spots

* For Standard Meteorological Week see Annexure-II

- **Case Studies**

Season	Crop	Operation	Weather parameter crucial to the crop the	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS Recommendation followed	What is the loss/gain achieved due to the recommendation (AAS vs non AAS)	
						Total cost of cultivation	In Net returns
Rabi-03	Palak Hyderabad	Pesticides spraying	Cloudy weather & Drizzling	Jan 27 2004 (Carbendazim)	Yes	Rs. -570.3 (5.76%)	Rs. 4129.2 (26.75%)
Rabi-04	Palak	Pesticides application	Cloudy weather	Mar 11 2005 (COC)	Yes	Rs. 703.5 (6.22%)	Rs. 1537.3 (8.68%)

- **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Hyderabad	Palak	Decrease by 9.4%	Increase by 24.6%	Increase by 25.1	Increase by 24.4%

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Input	Amount of input used (kg/acre)		Difference in yield due to input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seed (kgs/acre)	70	62	17.5	14.0	3.4	23522	25955	-2433
Fertilizer kg/acre)	787	833						
Pesticide kg/acre)	51	71						
Human labour (mandays/acre)	189	172						
Machine labour (hrs/acre)	31	28						
Irrigation (no/acre)	5	5						

- **Tomato**

  - **AAS units undertaking study on Tomato**

Hyderabad	Season: Rabi
Coimbatore	Season: Kharif
Solan	Season: Kharif (Mar-Aug)
Bangalore	Season: Rabi
Bhubaneshwar	Season: Rabi

  - **General Information of the crop**

Tomato a warm season vegetable and is also grown extensively in cool season. The optimum temperature required for its cultivation is 15-27$_o$C. At high and low temperatures there is a low germination of seeds, poor plant growth, flower drop, poor fruit set and ripening. Under extreme high and low temperature conditions, yield and quality of fruit is reduced. Mild winter condition is ideal for seed germination, plant growth, fruit set, fruit development, and ripening. Extensive rains adversely affect its fruit set causing flower drop. Sandy loam soils rich in organic matters are ideal for its cultivation. For raising healthy crop, application of green manure, FYM, Neem cake and bio-fertilizers are beneficial. Boron and Zinc are important micro nutrients, required for realizing higher yields. Frequent irrigation is essential for optimum plant growth, fruiting and yield. The crop should be irrigated at 8-12 days interval. Generally open furrow method of irrigation is followed. Multiple picking are taken in tomatoes. The crop is prone to insect pests like sucking pests, fruit borer, leaf miner, and diseases like leaf spots, blight and viral diseases. The triggering events for the above pest and diseases are maximum, minimum temperatures, humidity and rainfall.

  - **Weather sensitive farm operation**

Sowing, Irrigation, Plant protection, Fertilizer application, weeding, irrigation, picking and harvest

- **Weather sensitive crop growth stages**

Crop	Station	Crop growth stage	Standard Met. Week*	Important weather parameter related to respective crop growth stage	Effect of weather parameter
Tomato	Hyderabad	Sowing	40	Rainfall	Timely sowing
		Seedling	41-44	Rainfall, cloud cover	Seedling diseases
		Vegetative	45-48	Cloud cover and rainfall	Incidence of leaf spots and blight
		Flowering and Fruiting	49-60	Cloud cover, temperature And rainfall	Incidence of insect pests, leaf spots, blight and viral diseases
Tomato	Coimbatore	All stages		Temperature	Day temperature 36°C and Night temperature 18°C favours tomato growth. Tomato planted in June/ November /December gives higher yield and fetches good price. High temperature during summer season makes the Pollen to wither and pollination is greatly affected. High temperature makes the leaves to curl .To reduce the ill effects of high temperature mulching can be practiced.
		All stages		Rainfall	Rainy weather is favourable for leaf spot disease.
Tomato	Bangalore	**Early sown** – Vegetative & flowering stage	8	Rainfall & Relative humidity	Due to high humidity and rainfall causes high incidence of leaf curl and fruit rot.
		Timely sown - Vegetative & Flowering stage	10	Rainfall, temperature and relative humidity	Heavy rainfall causes high incidence of leaf curl and fruit rot.

* For Standard Meteorological Week see Annexure-II

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Station: Hyderabad

Input	Amount of input used		Difference in yield due to input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seed (gms/acre)	913	772	280	246	34	34253	34648	-395
Fertilizer kg/acre)	856	899						
Pesticide kg/acre)	13	12						
Human labour (mandays/acre)	176	154						
Machine labour (hrs/acre)	16	15						
Irrigation (no/acre)	5	6						

Station: Solan

Input	Amount of input used		Difference in yield due to input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seedlings (100 per bundle)	85	113	107	85	22	18790	11973	6817
FYM (kg/acre)	2079	1374						
Fertilizer kg/acre)	190	25						
Pesticide (kg/acre)	7	5						
Human labour (mandays/acre)	82	63						

Station: Bhubaneshwar

Input	Amount of Input used		Difference in yield due to the input (Rs/Acre)			Difference in the cost of cultivation (Rs./acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (gms/acre)	330	275	16876	13676	3200	6330	4906	1424
FYM (kg/acre)	1500	960						
Fertilizer (kgs/acre)	913	590						
Pesticide (kgs/acre)	596	250						
Human labour (mand/ac)	1575	1575						
Machine labour (hr/acre)	580	626						
Irrigation (no/acre)	530	515						
Assoc.cost (Rs/acre)	306	115						

Station: Bangalore

Input	Amount of Input used		Difference in yield due to the input (Rs/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (gms/acre)	2711	2840	19084	17867	1217	9850	10532	-682
FYM (kg/acre)	954	1017						
Fertilizer (kgs/acre)	995	1112						
Pesticide (kgs/acre)	196	302						
Human labour (mand/ac)	2469	2667						
Bullock labour (hr/acre)	167	233						
Machine labour (hr/acre)	1258	1258						
Irrigation (no/acre)	1100	1100						

Station: Coimbatore

Input	Amount of Input used		Difference in yield due to the input (Rs/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (gms/acre)	76	86	89	79	10	5532	5885	-353
Fertilizer (kg/acre)	318	332						
Pesticide (kgs/acre)	4	5						
Human labour (mandays/acre)	101	94						
Machine labour (hr/acre)	5	6						
Irrigation (no/acre)	12	13						

- **Case Studies**

Season	Crop	Operation	Weather parameter crucial to crop the	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS Recommendation followed	What is the loss/gain achieved due to the recommendation (AAS vs non AAS)	
						In Total cost of cultivation	In Net returns
Rabi-04	Tomato Hyderabad	Pesticides application	Cloud cover, Rainfall	Dt .Nov 5 2004 (Mancozeb)	Yes	Rs. 700 (5.63%)	Rs.2000 (11.32 %)
Rabi 2005		Pesticides spraying	Temperature	Dt. Dec 13 2005, (Dimethoate)	Yes	Rs. 394 (3%)	Rs. 2267 (10%)
Kharif 2004	Tomato Coimbatore	Irrigation	Rainfall	Aug 3 2004; Sep 14 2004 ; rain expected so save irrigation cost	Yes	-	Rs. 7440
Rabi2004-05	Tomato Bangalore	Inter cultivation Plant protection and staking measures and harvesting	Rainfall and Relative humidity and temperature	Dec 24, 25, 27 and 29 2004 and Jan 6 7 8 and 9 2005 Recmm: No rain is forested go for Inter cultivation , spraying and harvesting the crop	Yes	876 / ac	1800 /ac

- **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Bhubaneshwar	Tomato	Increase by 10.9%	Increase by 11.2%	Increase by 11.4%	Increase by 23.4%
Bangalore	Tomato	Decrease by 6.5%	Increase by 6.8%	Increase by 25.9%	Increase by 6.8%
Coimbatore	Tomato	Decrease by 1.6%	Increase by 12.3%	Increase by 16.3%	Increase by 14.6%
Hyderabad	Tomato	Decrease by 1.14%	Increase by 19.0%	Increase by 30.2%	Increase by 13.7%
Solan	Tomato	Increase by 56.94%	Increase by 77.14%	Increase by 80.93%	Increase by 26.09%

- **Capsicum**

  - **AAS units undertaking study on Capsicum**

    Solan Season: Kharif (March-August)

  - **General information of crop**

Capsicum also known as *Shimla Mirch* is mostly cultivated in loamy or sandy loam soils rich in organic carbon matter with pH of 6-7. Heavy soils are also favourable under rainfed conditions. But in Himachal Pradesh it is widely cultivated under irrigated conditions. The major source of irrigation is natural resources like *spring water.*. The Capsicum are sown by indirect methods where in seedlings are raised in nurseries. After the seedlings attain a height of 10-15 cm in 4-6 weeks, they are transplanted in the pits made at a distance of 45x45 cm. Transplanting is mainly carried out in the evening. The crop require frequent irrigation with well drainage system. The most critical stages are flowering and fruit setting. Ripe fruits are harvested at frequent intervals. Post harvesting handling of Capsicum is most important for uniform colour development.

  - **Weather sensitive farm operations**

Sowing, transplanting, irrigation are some the weather sensitive farm operations.

  - **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Solan	Capsicum	Increase by 2.18%	Increase by 57.28%	Increase by 61.26%	Increase by 20.07%

  - **Overall analysis of the results obtained in terms of use of weather based AAS**

Station: Solan

Input	Amount of input used		Difference in yield due to input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seedlings (100 per bundle)	117	134	44	37	7	19939	13103	6836
FYM (kg/acre)	2187	1379						
Fertilizer kg/acre)	222	30						
Pesticide (kg/acre)	7	5						
Human labour (mandays/acre)	83	63						

- **Onion**

  - **AAS units undertaking study on Onion**

    Pune Season: Rabi

  - **General information of crop**

Onion is an important commercial crop grown mostly in the *rabi* season in India. Red and white varieties of onion are cultivated in the country. India is the second largest producer of onion in the world with a production of 4 million tones. In India, the major onion growing states are Maharashtra, Gujarat, Karnataka and Andhra Pradesh.

Onion can thrive well under wide range of climate therefore, it can be grown in all the seasons or year round. Extremes temperatures (heat/cold) or excessive rainfall are not suitable for growing onion. One ploughing followed by two to three harrowing are necessary for preparation of land. Mostly flat beds are preferred or it can be grown on ridges and furrow layout.

  - **Weather sensitive farm operations**

Ploughing, transplanting, irrigation, Weeding, Plant protection are some of weather sensitive farm operations.

  - **Weather sensitive crop growth stages**

Crop growth stage **Onion**	**Slandered Met. week***	**Important Weather parameter related to respective crop growth stage**	**Effect of weather parameter**
Sowing seeds	34	Warm Temperature	
Emergence in raised beds	35	Warm Temperature	Germination satisfactory
Seedling growth	35-41	Warm Temperature	Seedling growth satisfactory
Transplanting	42	Cool temperature. Humidity upto 85% Delay transplanting	Establishment & growth satisfactory Increased bolting
Vegetative growth stage	42-45	Cool temperature. Humidity upto 85%	Faster growth
Bulb formation stage	46	Cool temperature, Humidity upto 85%	Faster growth
Bulb development stage	47-	Cool temperature, Humidity upto 70%	Satisfactory growth

* For Standard Meteorological Week see Annexure-II

  - **Measuring the Impact of AAS**

Station	**Crop**	**Impact of AAS on cost of cultivation**	**Impact of AAS on gross returns**	**Impact of AAS on net returns**	**Impact of AAS on yield**
Pune	Onion	Increase by 0.9%	Increase by 20.4%	Increase by 30.1%	Increase by 30.2%

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Input	Amount of Input used		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (kg/acre)	3.5	3.4	30.2%			7979	7912	67
Fertilizer (kg/acre)	154	173						
Pesticide (kg/acre)	1.0	0.9						
Human labour (mandays/acre)	54	47						
Machine labour (hrs/acre)	19	15						
Irrigation (no: acre)	5.0	5.1						

- **Case Studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS recommendation followed	Gain/loss due to the recommendation (AAS vs Non AAS)
Rabi 04-05	Onion	Plant protection	Cool Temperature humidity up to 85%.	Nov 23 2004, Dec 212004, Dec 28 2004 There is decrease in minimum temperature the cold condition prevail during coming four days Thrips, jassids and leaf blight on onion should be controlled by spraying Endosulfan 2 ml + Dithane M-45, 3 gram per liter water.	Recommendation followed	The AAS farmers gained by 8-12% in total yield when compared to the non-AAs farmers by following the advisory
Rabi05-06		Sowing	Warm	Oct 25 & 28 2005Due to prediction of rise in maximum temperature the period is favorable for transplanting of onion seedlings on flat bed		
Rabi 06-07		Irrigation	Temperature	Nov 7 2006. Dry weather so Irrigate the crop at 10-12 days interval		
		Interculture	Cool Temperature, humidity up to 85%.	Do the interculture operation like weeding, hoeing.		

- **Potato**

  - **AAS units undertaking study on Potato**

    Anand Season: Rabi

  - **General information of crop**

Potato is generally grown in Kheda, Anand, Mehsana, and Banaskantha districts of State. Kufri Badshah, Kufri Pokhraj, Kufri Lauvker, Kufri Jawahar and Kufri Bahar are the important varieties of the crop. The crop requires cool climate. Sandy or sandy loam soil is favourable for the potato crop. Third week of November is optimum date of planting of potato. The crop requires fertilizer at the rate of 200+ 100 + 100 NPK kg/ha for proper growth and yield. Potato requires 8-10 irrigations at 8-10 days interval.

  - **Weather sensitive farm operation**

Sowing, plant protection and harvest are some of the important weather sensitive operations.

  - **Weather sensitive crop growth stages**

Crop growth stage Potato	Standard Met. Week*	Important weather parameter related to respective crop growth stage	Effect of weather parameter
Vegetative	49-50	Cloudy sky, rainfall, humidity	Cloudy sky or unseasonal rainfall followed by hot and humid days favours early blight disease.
	50-51	Cloudy sky, rainfall	Cloudy sky or unseasonal rainfall favours the angular leaf spot disease.
Tuber bulking	01-09	Cloudy sky, rainfall, humidity	Cloudy sky or unseasonal rainfall followed by hot and humid days, favours late blight disease.
Maturity/ Harvest	12-13	Soil temperature	High soil temperature causes rotting, degeneration and malformation in the tubers.

* For Standard Meteorological Week see Annexure-II

  - **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Anand	Potato	Decrease by 3.1%	Increase by 10.3%	Increase by 13.5%	Increase by 5.4%

- **Case Studies**

Season	**Crop**	**Operation**	**Weather parameter crucial to the crop**	**Date of AAS recommendation in light of the prevailing weather for that operation (write the recommendation also)**	**Whether AAS Recommendation followed**	**What is the loss/gain achieved due to the recommendation (AAS vs non AAS)**	
						In Total cost of cultivation	In Net returns
Rabi (2005-06)	Potato	Planting	Temperature	Nov 7 2006 The planting should be carried out in the first fortnight November or as per the optimum temperature of 22-23 º C	Yes	. AAS farmer saved Rs. 692/acre by following timely planting of potato.	Higher net return (Rs. 37889/acre) as compared to Non-AAS farmers(Rs. 33179/acre).
Rabi (2006-07)	Potato	Irrigation	Rainfall	Dec 10-12 2006 As no forecast of rainfall, go for irrigation	Yes	AAS farmers have invested Rs. 748/acre for irrigation as per the advice of AAB. The Non-AAS farmers spent Rs. 186/acre more by not applying required irrigation at proper time.	Higher net return to the tune of Rs. 31716/ace as compared to Non-AS farmers (Rs. 28167/acre).

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Input	**Amount of Input used (Rs/acre)**		**Difference in yield due to the input (q/acre)**			**Difference in the cost of cultivation (Rs/acre)**		
	AAS	**Non-AAS**	**AAS**	**Non-AAS**	**Difference**	**AAS**	**Non-AAS**	**Difference**
Seed	1174	1060	84	78	6	1547	1596	-49
Fertilizer	232	209						
Irrigation	7	7						
Pesticide	1	1						

(d) Cash crops : Cotton, Jute

- **Cotton**
  - **AAS units undertaking study on Cotton**

Hyderabad	Season: Kharif
Hisar	Season: Kharif
Coimbatore	Season: Rabi (August-February)

  - **General information of crop**

Cotton is grown in an area of 10 lakh hectares in black cotton soils under rainfed conditions of Andhra Pradesh during Kharif season. In Hisar, Cotton crop is sown in May (timely sowing) under assured irrigation facilities. In Coimbatore its normal date of sowing is around 15th August. It is a commercial crop grown under high input conditions. Cotton is an indeterminate plant and any weather aberrations during crop season will adversely effect the square, flower and boll shedding. It cannot stand continuous wet and overcast weather at any stage. Low light intensities lower the yield. The optimum temperature range for vegetative growth is 21-27^{o}C. During the period of fruiting, warm days and cool nights with large diurnal variations are conducive for good boll and fiber development. Since it is grown under high input conditions, it is prone to severe pest and diseases. Many of the pests and diseases are weather driven, right advice at right time based on the weather will help in effective control of pests and diseases thereby reducing the expenditure and thereby improving the yields.

  - **Weather sensitive farm operation**

Sowing, Fertilizer application, Plant protection, Picking (Harvesting),irrigation are the weather sensitive farm operations.

  - **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Hisar	Cotton	Decrease by 4 %	Increase by 3.0%	Increase by 6 %	Increase by 23.3%
Coimbatore		Decrease by 6.13%	Increase by 0.6%	Increase by 16.9%	Increase by 0.8%
Hyderabad		Decrease by 18.19%	Increase by 2.2%	Increase by 20.5%	Increase by 0.8%

- **Weather sensitive crop growth stages**

Crop	Station	Crop growth stage	Standard Met. Week*	Imp weather parameter related to respective crop growth stage	Effect of weather parameter
Cotton	Hyderabad	Seedling stage	25-27	Rainfall	Timely sowing
		Vegetative	28-32	Rainfall and cloud cover	Incidence of sucking Pests
		Square initiation	33-34	Rainfall and cloud cover	Drop in flower buds and incidence of pests and diseases
		Flowering	35-39	Rainfall and cloud cover	Flower drop, attack of pests and diseases
		Boll initiation and development	36-42	Rainfall and cloud cover	Boll drop, attack of pests and diseases
		Boll maturity and harvest	43-47	Rainfall	Fiber damage
	Hisar	**Timely sown** Germination Flower bud/Square formation Boll development	19 & 20 31, 32 & 33 35, 36, 37 & 38	 Temp, moisture Temp, moisture Temp, moisture	 High temp burns young seedlings. High temp & moisture stress sheds flower buds/squares. High temp & moisture stress sheds bolls.
	Coimbatore	Establishment From sowing to head initiation		1. Air Temperature 2. Soil temperature	Optimum temperature is 18 to 21°C. Soil temperature <20°C – Liable for attack of seed borne pathogens and smothering by weeds.

		Vegetative stage -from head initiation to head emergence		1. Temperature	Minimum temperature for growth is 15°C; optimum temperature is 27 to 30°C, >38°C is harmful. Night temperature >21°C delayed the floral bud differentiation.
		Flowering -from head emergence to seed set		1. Rainfall 2. Temperature	1.Water stress will lead to early maturity 2. Rainfall during flowering reduces the yield 3. Severe water stress during flowering period cause pollination failure or head blast. 4. Boot leaf stages very sensitive to temperature 5. low temperatures (<15°C) and high temperatures (>35°C) lead to poor seed set, problems with ripening and reduced yield Water sensitive stage
		Yield formation (from seed set to physiological maturity)		1. Temperature 2. Soil moisture stress 3. Diurnal variation	1. Optimum temperature 26°C 2. Temperature >28°C affects the yield 3. Soil moisture stress affects grain filling and reduces the yield 4. Day / night temperature regimes of 33/28°C arrested floral development. 5. Sensitive to water stress
		Ripening from physiological maturity to harvest		1. Rainfall	1. Cloudy and wet weather will favour head mould and sugary disease.

* For Standard Meteorological Week see Annexure-II

- **Case Studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation (write the recommendation also)	Whether AAS Recommendation followed	What is the loss/gain achieved due to the recommendation (AAS vs non AAS)	
						In Total cost of cultivation	In Net returns
Kharif 04	Cotton Hisar	Irrigation	Rainfall	23 July, 04 (Rain expected, withheld irrigation)	Followed	Loss in net returns	
		Spray	Temp& Cloudiness	21 Sept, 04 (No rains, spray crop)	Followed	Gain in total cost and net returns	
Kharif 06		Irrigation	Rainfall	4 July, 06 (No rain, spray crop)	Followed	Gain in total cost and net return	
Kharif 05	Cotton Hyderabad	Pesticides spraying	Cloud cover, Rainfall	Dt.09-08-2005 (Imidachloprid)	Yes	Rs. 2223 (18 %)	Rs. 2255 (22 %)
Kharif -06		Pesticides spraying	Cloud cover, Rainfall	Dt.29-09-2006 (Monocrotophos)	Yes	Rs. 3682 (26.39%)	Rs. 4361 (38.95%)
Rabi 2004	Cotton Coimbatore	Fertilizer application	Minimum Temperature	29-30Sep 2004. Decrease in minimum temperature expected, give top dressing of nitogenous fertilizer	Yes	Gain in net returns as well as in the yield	

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Station: Hisar

Input (per acre)	Amount of Input used		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (kg)	5	5	10.6	8.6	2.0	11550	12377	- 827
Fertilizer (kg)	105	90						
FYM (ton)	4	--						
Irrigation (No.)	3	5						
Herbicide	--	--						
Pesticide (Rs)	879	834						
Labour (Rs)	3000	3300						

Station: Coimbatore

Input	Amount of input used		Difference in yield due to input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seed (gms/acre)	3.5	3.6	12.6	12.2	0.4	4420	4660	-240
Fertilizer (kg/acre)	269	262						
Pesticide (kgs/acre)	2	3						
Human labour (man days/acre)	49	59						
Machine labour (hr/acre)	12	16						
Irrigation (no/acre)	12	13						

Station: Hyderabad

Input	Amount of input used		Difference in yield due to input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seed (kg/acre)	7.8	7.2	24.8	24.6	0.2	27454	33560	-6106
Fertilizer kg/acre)	233	302						
Pesticide kg/acre)	5	8						
Human labour (mandays/acre)	42	34						
Machine labour (hrs/acre)	8	10						
Irrigation (no/acre)	0.5	0.4						

- **Jute**

  - **AAS units undertaking study on Jute**

    Kalyani Season: Kharif

  - **General information of crop**

Jute crop from its sowing to harvesting faced several constrains . Usually Farmers of this zone sown the crop using pre monsoon shower but in the last year amount and distribution of pre monsoon rain was very poor . So they faced severe problems during sowing time . Some marginal and Progressive farmers sown their crop using irrigation. Onset of monsoon was in time but break of monsoon during active vegetative period created water stress.

Due to high humidity and temperature variation initiation of various insect and disease was observed like Bihar hairy caterpillar, Jute semilopper rotting etc . The intensity was so severe that NAAS farmers were confused to control the infestation and get help from us regarding this matter. Lastly in the harvesting, retting and washing crop was in critical condition due to lack of rainfall.

  - **Weather sensitive farm operation**

Raising of seedling; Plant protection; Harvesting; Retting

  - **Weather sensitive crop growth stages**

Crop	Station	Growth stages	Important weather elements	Weather parameters
Jute	Kalyani	Germination	Temperature Rainfall	1-2 pre-sowing irrigation is needed for optimum germination if rain breaks during germination period with severe heat.
		Vegetative stage	1. Temperature 2. Rainfall 3. Wind 4. Humidity	High temperature, high moisture content, high relative humidity and mild wind are required for optimum growth of jute crop. Low temperature (< 20 ^{0}C) at this stage cause premature flowering, and thereby deteriorates quality of the fiber.
		Harvesting & Retting	1. Temperature 2. Rainfall	Optimum temperature is (34 ^{0}C) essential for good retting and good quality of water required for good fiber.

  - **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Kalyani	Jute	Decrease by 24.9%	Increase by 11%	Increase by 21%	Increase by 14.1%

- **Case studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation (write the recommendation also)	Whether AAS Recommendation followed	What is the loss/gain achieved due to the recommendation (AAS vs non AAS)	
						In Total cost of cultivation	In Net returns
	Jute	a)Raising of seedling b) Plant protection c) Harvesting d) Retting	Temperature Rainfall Wind Humidity	1. Some times at high temperature with severe drought results dry up the seedlings. 2. Optimum temperature 22 to 30°C 3. 5-7 cm water require for active root development. 4. Very high wind speed leads to lodging of seedlings and tip drying .(50DAS)		• Rs.1915 per acre could be saved by AAS compared to NAAS in total cost of cultivation by following the AAS recommendation. • The yield for AAS was higher by 0.83 Q/acre (main product and 1.05 Q/acre (By product) as compared to the NAAS.	

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Input	Amount of Input used		Difference in yield due to the input			Difference in the cost of cultivation(Rs./acre)		
	AAS	Non-AAS	AAS (Q/Acre)	Non-AAS (Q/Acre)	Difference (Q/Acre)	AAS	Non-AAS	Difference
Seed (Kg/acre)	2.5	3	33	29	4	4510	6005	-1495
Fertilizer (Kg/acre	48	56						
FYM	0	0						
Irrigation (no./acre)	1	0.3						
Plant protection chemical	0	0						
Herbicide	0	0						
Pesticide (lts./acre)	0.5	0.7						

- **Tobacco**

  - **AAS units undertaking study on Tobacco**
    Anand Season: Kharif

  - **General information of crop**

Bidi tobacco is generally grown in Anand, Vadodara, Kheda and Panchmahals districts. For irrigated region, the high yielding varieties are Anand-2, Anand-119, Gujarat Ttobacco-5, Gujarat Tobacco-9 and Gujarat Tobacco Hybrid-1. In some parts of Panchmahals district Anand-119 is grown as unirrigated crop. Tobacco is transplanted during 2nd week of August to 3rd week of September. Crop requires 3 to 4 irrigations at 20 days interval. Crop is transplanted after green manuring of sunhemp. The chemical fertilizer requirement is 180 + 0 +0 NPK kg/ha.

  - **Weather sensitive farm operation**

Seedling, irrigation application, spray, harvesting are the main weather sensitive operations.

  - **Weather sensitive crop growth stages**

Crop growth stage	Standard Met. Week*	Important weather parameter related to crop growth stage	Effect of weather parameter
Seedling	30-33	Temperature, Humidity	High moisture cause damping off
Vegetative	40-44	Temperature	High temperature deteriorate the leaf quality
	45-52	Soil moisture, temperature	High soil moisture and low temperature favours growth of *Orobanche*
	49-05	Temperature	Low temperature favours the leaf curl disease
Maturity	9-13	Rainfall	Rainfall deteriorate the leaf quality
Harvesting	9-13	Cloudiness, rainfall	Cloudy sky and rainfall affect the quality of the leaves during harvesting and sun drying.

* For Standard Meteorological Week see Annexure-II

  - **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Anand	Tobacco	Increase by 2.8 %	Increase by 11.7%	Increase by 21.5 %	Increase by 0.9%

- **Case Studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS Recommendation followed	What is the loss/gain achieved due to the recommendation (AAS vs non AAS)	
						In Total cost of cultivation (Rs/acre)	In Net returns (Rs/acre)
Kharif (2005-06)	Tobacco	Fertilizer application	Rain fall	15/8/2005 As there was no forecast for rainfall, the recommended basal dose of fertilizer should be applied	Yes	AAS farmers invested total 1535 Rs/acre for timely application of top dressing. He only invested Rs. 17 /acre as compared to Non-AAS farmer.	By timely application of fertilizer his net return was higher to the tune of Rs. 667/acre as compared to Non-AAS farmer.
Kharif (2006-07)		Irrigation	Rain fall	16 to 19/1/2007 light irrigation recommended for tobacco	Yes	AAS farmers invested total Rs. 700/acre for irrigation as per the AAB advisory. AAB advised irrigation need based time and frequency of irrigation. For timely and effective irrigation he has invested only Rs. 150/acre more as compared to Non-AAS farmers.	By timely application of irrigation as per the crop need his net return was higher to the tune of Rs. 655/acre as compared to Non-AAS farmers.

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Input	Amount of Input used (Kgs/Acre)		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed	2	2	6.4	4.5	0.9	760	739	21
Fertilizer	184	209						
Irrigation	6	6						
Pesticide	1	1						

(e) Oil Seeds : Mustard

- **Mustard**

  - **AAS units undertaking study on Mustard**

    Hisar Season: Rabi
    Kalyani Season: Rabi

  - **General Information about the crop**

In India rape and mustard is grown during winter season and it is observed that the crop needs about 18^0C to 25^0C temperature, low humidity, practically no rain especially at the time of flowering. Rainfall, high humidity and cloudy weather are not good for the crop during winter, as it invites aphids and the crop gets spoiled completely. However, under rainfed conditions one to two pre-flowering rains help in boosting the grain yield. Excessive cold and frost are harmful to the crop.

Generally the rape and mustards thrive best in medium or heavy loam soils except taramira which is grown lighter soils butt heavy soils subjected to water logging should be avoided as the crop cannot tolerate such conditions. Though the crop is grown during winter season and there is very little chance of water logging but still due to heavy winter rains the water may get accumulated and cause a temporary water logging. Very light soils usually cause a serious moisture stress and a poor crop growth is observed. Saline and alkaline soils are often not fit for the crop though it has good tolerance to such conditions.

  - **Weather sensitive farm operation**

Sowing, land preparation, irrigation application, chemical spray, harvesting and threshing were the weather sensitive operations.

  - **Measuring the Impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Hisar	Mustard	Decrease by 6 %	Increase by 3.9%	Increase by 7 %	Increase by 16.7%
Kalyani	Mustard	Decrease by 17.3%	Increase by 11.3%	Increase by 14.3%	Increase by 0.5%
Jodhpur	Mustard	Decrease by 1.8 %	Increase by 9.5 %	Increase by 23 %	Increase by 7.14 %

- **Weather sensitive crop growth stages**

Crop	Station	Crop growth stage	Standard Met. Week *	Imp. weather parameter related to respective crop growth stage	Effect of weather parameter
Mustard	**Hisar**	**Timely sown**			
		Germination	42 & 43	Temp	High temp burns young seedlings
		Flowering	51 & 52	Temp, fog etc	Low temp & fog hinder flower & siliquae formation
		Seed setting	1 & 2	Temp, cloudiness, fog Temp	Low temp & fog hinder seed setting Small seed size due to high temp
		Ripening	10, 11 & 12	Temp	Low temp & fog hinder germination Low temp & fog hinder flower & siliquae formation
		Late sown			
		Germination	45 & 46	Temp, fog etc	Low temp & fog hinder seed setting
		Flowering	1 & 2	Temp and fog	High temp causes force maturity
		Seed setting	2 & 3		
		Ripening	11,12 &13	Temp	
	Kalyani	Vegetative /branching		Temperature Rainfall, Wind	Low temperature favours the growth. High temperature and cloudy weather is not favorable for growth and also cause infestation of aphid. High rainfall is not good but rain at branching and pre-flowering stage is beneficial of good yield. Very high wind speed leads to lodging of seedlings and tip drying.
		Harvesting and threshing		Temperature Relative humidity Light	Low temperature increase the oil percentage Optimum temperature 32 to 34°C. Bright sunshine is required for threshing and drying of the grain.

* For Standard Meteorological Week see Annexure-II

- **Case Studies**

Season	**Crop**	**Operation**	**Weather parameter crucial to the crop**	**Date of AAS recommendation in light of the prevailing weather for that operation (write the recommendation also)**	**Whether AAS Recommendation followed**	**What is the loss/gain achieved due to the recommendation (AAS vs non AAS)**	
						In Total cost of cultivation	**In Net returns**
Rabi04-05	Mustard Kalyani	(a) Land preparation (b) Sowing (c) Plant protection (d) Harvesting and threshing	Temperature Relative humidity Light Wind	1. Low temperature favours the growth. 2. High temperature and cloudy weather is not favourable for growth and also cause infestation of aphid. 3. High rainfall is not good but rain at branching and pre-flowering stage is beneficial of good yield. 4. Very high wind speed leads to lodging of seedlings and tip drying. (30DAS)	Yes	• Rs.940 per acre could be saved by AAS compared to NAAS in total cost of cultivation by following the AAS recommendation. • The yield for AAS were higher by 0.02Q/acre as compared to the NAAS.	
Rabi 05-06	Mustard Jodhpur	Plant protection	Cloudy weather	Middle of December to Middle of February	Yes	Rs 200-250/-	Rs. 1500/-
Rabi 06-07	Mustard Hisar	Sowing	Rainfall	10 Oct, 06 (No rain, sowing on conserved soil moisture	Followed	Less total cost, gain in net returns	
		Irrigation	Temp	2 Jan, 07 (Frost likely, irrigate crop)	Followed	Gain in total cost and net return	
		Spray	Rainfall	6 Feb, 07 (No rain, spray crop)	Followed but heavy rains followed	Gain in total cost and loss in net return	

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Station: Hisar

Input(per acre)	Amount of Input used (Kg/acre)		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (kg)	2	2	6.3	5.4	0.9	5814	5887	-73
Fertilizer (kg)	120	95						
FYM (ton)	--	--						
Irrigation (No.)	2	3						
Herbicide	--	--						
Pesticide Rs)	451/-	390/-						
Labour (Rs)	1400/-	1475/-						

Station: Kalyani

Input (acres)	Amount of Input used (Kg/acre)		Difference in yield due to the input (Q/Acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed (Kg)	3.4	3.8	6.3	5.8	0.5	4485	5425	-940
Fertilizer Kg)	50	55						
FYM	0	0						
Irrigation (no.)	2	2						
Plant protection chemical								
Herbicide	0	0						
Pesticide (lts)	0.5	0.5						

(f) Pulses : Gram, Redgram/Tur, Field Bean

- **Gram**

  - **AAS units undertaking study on Gram**

    Raipur Season: Rabi
    Jaipur Season: Rabi

  - **General information of crop**

Gram requires cool and humid climate. The seeds of the crop can germinate over a wide range of temperature from 10 – 45°C. Temperature around the 15-20°C is optimum for its growth. The ideal soil temperature for the nodulation is 15-25°C. Soil temperature exceeding 30°C affects the nodulation. Excessive rains after the sowing and at flowering are harmful. The highest pod formation has been received at RH from 20-40%. Above this have negative influence on seed setting and below this results in reduced yield.

  - **Weather sensitive farm operation**:

Sowing, Plant protection and Harvesting operation.

  - **Weather sensitive growth stages**

Crop		Crop Growth Stage	Standard Met. Week*	Imp weather parameter related to respective crop growth stage	Effect of weather parameter
Gram	Raipur Timely sown	Flowering and pod formation	52	Cloudy weather	Incidence of insect pest along with powdery mildew
	Late sown	Pod Development	17	High temperature	Leads to forced maturity and small grains.
	Jaipur	Pre-flowering	50	Cloudy weather	cause blight
		Flowering	1	Frost attack	reduces yield
		Pod filling	7	Winter showers	spoils seeds

* For Standard Meteorological Week see Annexure-II

  - **Measuring the impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Raipur	Gram	Decrease by 3.2%	Increase by 14.1%	Increase by 47.7%	Increase by 16%
Jaipur	Gram	Decrease by 4.72 %	Increase by 8.91 %	Increase by 11.32 %	Increase by 7.14 %

- **Case studies**

Season	Crop	Weather Parameters Crucial to the crop	Date of AAS Recommendation in light of the prevailing Weather (Also write recommendation)	Whether AAS Recommendation Followed	What is the loss/gain Achieved due to recommendation (AAS Vs Non AAS)	
					In Total cost of Cultivation	In net returns
Rabi04-05	Gram Jaipur	Irrigation	In View of forecast of rains farmer are advised to defer irrigation at pod formation stage (23rd Jan., 2004)	Followed	Saving of Rs 111/acre	Contributed 19.5 percent to the net saving over non AAS
Rabi05-06		Interculture	Looking into the forecast of rains farmers are advised to defer hoeing and weeding (30th Dec., 2005)	Followed	Saving of human labour, thus saving in cost of cultivation by Rs 162.4/acre	Contributed 11.6 percent to the net saving over non AAS
Rabi (2006-7)		Plant protection	Looking into the drop in minimum temperature by 3-4 ^{O}C farmers are advised to adopt protection against frost (23 January, 2007)	Followed	Increases cost of cultivation by Rs 250.0 / Acre	Frost occurred and AAS farmers saved their crop against frost

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Station: Raipur

Input (per acre)	Amount of Input used		Difference in yield due to the input (Q/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Diff	AAS	Non-AAS	Difference
Seed (kg)	30	31	2.9	2.5	0.4	3372	3485	-113
Fertilizer(kg)	25	15						
Herbicide (kg)	0	0						
Pesticide(l)	1	1						
Human labour (mandays)	22	12						
Machine labour (Total hours)	4	4						
Irrigation (no.) (per farmer)	1	2						

Station: Jaipur

Input (acre)	Amount of input used		Difference in yield due to Input (Q/acre)			Difference in cost of cultivation (Rs/acre)		
	AAS	Non AAS	AAS	Non AAS	Diff	AAS	Non AAS	Diff
Seed (kg)	32	34	18	16	2	494	532	-38
Fertilizer (kg)	39	38						
Herbicide (kg)	0	0						
Pesticide (kg)	1	0						
Human labour (mandays)	23	27						
Machine labour (hrs)	6	6						
Irrigation (no)	2	2						

- **Redgram/Tur**

  - **AAS units undertaking study on Redgram**
    Bangalore Season: Kharif

    - **General information of Crop**

Redgram **(***Cajanus cajan*) is the second most important pulse crop which constitutes 14.44 % and 15.95 % national pulse acreage and production with a productivity of 1200 kg/ha. It has multiple uses . Pigeon pea is perennial and perhaps evolved as a backyard crop. It is a warm season crop but adapts well to lower altitudes of tropics and subtropics (0 to 1500m), in well-distributed rainfall of 500-900mm. Temperature regime is 10˚ to 40˚C but optimum is 20 to 28˚C. It is a mesophyte well adapted to drought prone areas but does not tolerate water logging and frost. Root system is deep and expansive and breaks the plough pan hence it is called a 'biological plough'.

It is grown in wide range of soils. The most suitable pH range is 5 to 8; pigeonpea tolerates salinity and alkalinity to certain extent. The critical EC is 1.5 dsm^{-1}. But does not tolerate acidity, due to Al toxicity. However, this can be corrected by liming.

- **Weather sensitive farm operation**

The weather sensitive farm operation is earthing up, plant protection measures and harvesting.

- **Weather sensitive crop growth stages**

Crop		Crop growth stage	Std Met. Week*	Important weather parameter related to respective crop growth stage	Effect of weather parameter
Redgram /tur	**Bangalore Early sown**	–Vegetative & flowering stage	18	Rainfall & Relative humidity	Dry weather Abortion of flowers, high incidence of pod borer
	Timely sown -	Vegetative & Flowering stage	22	Rainfall, temperature and relative humidity	Due to prolong dry spells at flowering & pod formation stage results in poor yields, lack of moisture at harvest stage is a major problem leads to poor grain filling and lesser yields.
	Late sown	– Pod development and harvest	26-28	Rainfall, wind speed and relative humidity.	.High incidence of pod borer as a result causes reduction of pod yield.

* For Standard Meteorological Week see Annexure-II

- **Measuring the impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Bangalore	Red gram	Decrease by 14.1%	Increase by 14.8%	Increase by 32.7%	Increase by 14.8%

- **Case studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation (write the recommendation also)	AAS Rcmm followed	What is the loss/gain achieved due to the recommendation (AAS vs. non AAS)	
						In Total cost of cultivation	In Net returns
Kharif 2005	Red gram	Inter cultivation , Plant protection measures and harvesting	Rainfall and Relative humidity	22, 23, 25 Sept , 28-30 August , 17,19,20 and 21 Jan06 Recon : No rain is forested go for spraying, it should be before initiation of flower and harvesting the crop	Yes	762 / ac	2523 /ac
Kharif 2006	Red gram	Inter cultivation , Plant protection measures and harvesting	Rainfall and Relative humidity	25-27 Sept and 12-19 Oct and 1-3 Nov Recon : No rain is forested go for spraying and harvesting the crop	Yes	549 / ac	1399 /ac

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Input	Amount of Input used In (Rs/acre)		Difference in yield due to the input In (Rs/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed	110	125	14236	12405	1831	4078	4751	-673
FYM	880	1152						
Fertilizer	517	609						
Pesticide	393	523						
Human labour	1120	1317						
Bullock labour	200	167						
Machine labour	858	858						

- **Field Bean**

  - **AAS units undertaking study on Field Bean**
    Bangalore Season: Rabi

  - **General information of crop**

Field bean (*Dolichos lablab L.*) is one of the most ancient among the cultivated crop. It is grown throughout the tropical regions of Asia, Africa and America. The crop is multipurpose and can be used as pulse, vegetable forage but farmers grow it for seed purpose due to high profit over the other sources. It is indigenous and commercially cultivated in Karnataka, Madhya Pradesh, Tamil Nadu, Andhra Pradesh and Maharashtra. It is relatively cool season crop and it is best adapted to tropical and sub-tropical areas. Most of the varieties grow well in temperature ranging between 18˚C to 30˚C. Severe frost damages the crop. The crop is sensitive to photoperiod and both short day and long day types are available. It can be grown in wide range of soil except alkaline and saline soils.

  - **Weather sensitive farm operation**

The weather sensitive farm operation is earthling up, plant protection measures and harvesting.

  - **Weather sensitive crop growth stages**

Crop growth stage	Std Met. Week*	Important weather parameter related to respective crop growth stage	Effect of weather parameter
Early sown –Vegetative & flowering stage	15	Rainfall relative humidity and temperature	Dry weather Abortion of flowers, high incidence of pod borer
Timely sown -Vegetative & Flowering stage	18	Rainfall and relative humidity	Due to heavy moisture stress at flowering & pod formation stage is a major problem which leads to poor pod filling and lesser yields.
Late sown – Pod development and harvest	20-22		Due to severe moisture stress results in poor pod yield.

* For Standard Meteorological Week see Annexure-II

- **Measuring the impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Bangalore	Field bean	Decrease by 9.9%	Increase by 11.8%	Increase by 19.3%	Increase by 10.4%

- **Case studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation	AAS Recomm followed	What is the loss/gain achieved due to the recommendation (AAS vs. non AAS)	
						In Total cost of cultivation	In Net returns
Rabi-2005-06	Field bean	Inter cultivation , Plant protection measures and harvesting	Rainfall Relative humidity and temperature	July 1 -4 and Feb 19- 20 June Recon : No rain is forecasted go for Inter cultivation , spraying and harvesting the crop	Yes	760 / ac	4434.6 /ac

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Input	Amount of Input used (Rs/acre)		Difference in yield due to the input (Rs/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Seed	294	329	35304	31580	3724	7314	8126	-812
FYM	995	1124						
Fertilizer	869	986						
Pesticide	97	148						
Human labour	2574	2980						
Bullock labour	200	267						
Machine labour	886	892						
Irrigation	1400	400						

(g) Fruits : Banana

- **Banana**

  - **AAS units undertaking study on Banana**
    Thrissur Season: Kharif & Rabi
    Coimbatore Season: Annual

- **General information of Banana**

Banana is chief fruit crop in Kerala. Nendran banana is well known for banana chips. Other than Nendran, many varieties of banana are cultivated across the State Banana is cultivated during *kharif* season (Feb/Mar) as rainfed (mainly local varieties) and during *Rabi* season as irrigated. Mainly Nendran variety is grown and its harvest coincides with Onam festival. A total area of 50871 ha is under banana cultivation in Kerala. It is also extensively grown in Coimbatore in Tamil Nadu.

- **Weather sensitive farm operation**

Planting; use of fertilizer application; crop protection measures, harvesting

- **Weather sensitive crop growth stages**

Crop		**Crop growth stage**	**Standard Met. Week ***	**No. of days**	**Important weather parameter related to respective crop growth stage**	**Effect of weather parameter**
Banana	***Thrissur Kharif* season**	Vegetative stage	10 – 19th week (March 5 – May 13)	70	Failure of pre-monsoon showers	Planting of rainfed banana will be done with the available soil moisture. Failure of pre-monsoon showers will largely affect sucker establishment and its development.
		Harvesting stage	23-30th week (June 4 – July 29	56	Heavy rainfall and wind	Heavy rainfall along with wind will destroy the banana plantation. Continuous heavy rainfall during this period will lead to inundation of field and physiological function will be affected
	***Rabi* season**	Planting	46-06th Week (Nov 12-Feb 11)	91	High wind speed	High wind speed during this stage cause lodging of plant
		Vegetative stage	40-45th week (Oct 1 - Nov 11)	42	Heavy rainfall	Rainfall during this period will affect the planting operation
		Vegetative stage	23-30th week (June 4 – July 29)	56	Heavy rainfall and wind	Heavy rainfall along with wind will destroy the banana plantation. Continuous heavy rainfall during this period will lead to inundation of field and physiological function will be affected.
	Coimbatore Annual	Flowering and fruiting			wind	High wind speed damages the crop heavily

* For Standard Meteorological Week see Annexure-II

- **Measuring the impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Thrissur	Banana (Irrigated)	Increase by 4.3%	Increase by 4.3%	Increase by 26.4%	Increase by 11.1%
Thrissur	Banana (Rainfed)	Increase by 13.0%	Increase by 11.6%	Increase by 26.5%	Increase by 10.1%
Coimbatore	Banana	Increase by 25%	Increase by 9.1%	Increase by 7.7%	Increase by 9.3%

- **Case Studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS Recommendation followed	What is the loss/gain achieved due to the recommendation (AAS vs non AAS)	
						In Total cost of cultivation (Rs/ac)	In Net returns (Rs/ac)
Thrissur Kharif 05	Banana	Spraying	Cloudy weather, high relative humidity and low temperature	June 7, July 12, 19, August 2, 9 & 18, 2005 Recommendation: Against Sigatoka leaf disease in banana, spray 1% Bordeaux mixture or Tilt (25 EC) after cutting the severely affected leaves and burning it.	43 per cent of farmers were followed	5872	4136
Thrissur Rabi 05-06	Banana	Spraying	Population build up starts from March and peak during rainy season	March 28, May 9 and June13, 2005. Recommendation: Pseudo stem weevil attack has noticed in Nendran banana. To control this, affected plants may be sprayed with Carbaryl 50 WP	53 per cent of farmers were followed	-4457	13224
Thrissur Rabi 05-06	Banana	Strengthening of propping and drainage	Heavy rainfall and wind speed	June 20 & 27, 2006 Recommendation: Light to moderate rainfall is being expected in and around Thrissur district.	Heavy rainfall occurred	-11142/- loss in cost of cultivation Due to this extreme rainfall event there was 12 per cent yield loss & and 20.3 % loss in net return	

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Station: Thrissur

Input	**Amount of Input used (kg/acre)**		**Difference in yield due to the input (Q/acre)**			**Difference in the cost of Cultivation (Rs/acre)**		
	AAS	**Non-AAS**	**AAS**	**Non AAS**	**Diff**	**AAS**	**Non-AAS**	**Diff**
Banana (Irrigated) *Rabi* season								
Seed	995	1007	121	109	12	62834	60342	1492
Fertilizer	3469	3422						
FYM	7726	6451						
Irrigation	14	15						
Herbicide	N/A	N/A						
Pesticide	21	14						
Banana (Rainfed) *Kharif* season								
Seed (Suckers)	1000	1000	97	86	11	35632	31532	4100
Fertilizer	2784	1578						
FYM	4058	3896						
Pesticide	21	18						

Station: Coimbatore

Input	**Amount of input used**		**Difference in yield due to input (Q/acre)**			**Difference in cost of cultivation (Rs/acre)**		
	AAS	**Non AAS**	**AAS**	**Non AAS**	**Diff**	**AAS**	**Non AAS**	**Diff**
Banana Suckers Seed (no:)	1252	1234	212	196	17	9466	7660	1806
Fertilizer (kg/acre)	1326	1068						
Pesticide (lit/acre)	1	1						
Human labour (manays/acre)	54	53						
Machine labour (hrs/acre)	3.2	3.8						
Irrigation (no/acre)	7	9						

- **Coconut**

  - **AAS units undertaking study on Coconut**

    Thrissur Season: Kharif

  - **General Information of the crop**

The State of Kerala ranks first in coconut area (49.6%) and production (44.7%) in our country. The name Kerala is derived from its association with the coconut palm called *Kera viriksha* in Sanskrit and coconut oil is major oil for culinary purpose. In Kerala, coconut is mostly cultivated as rainfed, in an area of 905718 ha and average productivity is 6049 nuts/ha. Kozhikode district stands first in area under coconut (130100 ha) and Thrissur district accounts 9.4 per cent area (85480 ha).

  - **Weather sensitive farm operation**

Sowing; Fertilizer application; Weeding; Irrigation; Picking; Plant protection

  - **Weather sensitive crop growth stages**

Crop	Plant	Growth stage	Standard Met. Week*	Weather Parameter and its range	Effect on Plant
Coconut	Thrissur	Various stages (Spath initiation and elongation spadix emergence, female flower production and button shedding)	48-19th week of next year (November 28 – May 13)	Prolonged dry spell and failure of pre-monsoon showers	Moisture stress leads to stunted growth, drooping of leaves, button shedding, immature nut fall and decrease in nut size and yield
		Various stage (Spath initiation and elongation spadix emergence, female flower production, Button shedding)	23-38th week (June 4 – September 23)	High relative humidity and low air temperature	Heavy rainfall leads to water logging, low nutrient uptake and coconut leaves showing yellowing in sand and sandy loam soil. High relative humidity and low air temperature congenial for bud rot disease

* For Standard Meteorological Week see Annexure-II

  - **Measuring the impact of AAS**

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Thrissur	Coconut	Increase by 14.2%	Increase by 13.1%	Increase by 30.6%	Increase by 11.1%

- **Case Studies**

Season	Crop	Operation	Weather parameter crucial to the crop	Date of AAS recommendation in light of the prevailing weather for that operation	Whether AAS Recommendation followed	What is the loss/gain achieved due to the recommendation (AAS vs non AAS)	
						In Total cost of cultivation (Rs/acre)	In Net returns (Rs/acre)
Rabi 2003-04	Coconut	Husk burial and mulch-ing	Prolonged dry spell (No rains and high temperature (39.4°C)	September 30, 2003 Recommendation: It is ideal time for husk burial and mulching for moisture conservation/retention. Mulching may also be done with green/dry leaves, which add organic matter to the soil and reduces the soil temperature.	39 per cent of farmers followed husk burial and 61 per cent of farmers followed mulching	- 2734	1924

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Station: Thrissur

Input	Amount of Input used (kg/acre)		Difference in yield due to the input (nuts/acre)			Difference in the cost of cultivation (Rs/acre)		
	AAS	Non-AAS	AAS	Non-AAS	Difference	AAS	Non-AAS	Difference
Fertilizer	431	324	5098	4521	577	9381	8216	1165
FYM	906	956						
Irrigation	10	12.8						
Pesticide	0.8	0.5						

- **Peach & Apricot**

  - **AAS units undertaking study on Peach & Apricot**

    Solan Season: Kharif
    Solan Season: Kharif

  - **General Information of the crop**

It is well distributed through out the area. July alberta is high yield variety of peach. It is mainly used for canning and processing purposes by the national and international fruits processing units . Main bearing stage/ commercial stage starts from (6 to 20 years). Rajgarh belt is famous for the production of July Albrata peach in India, it's high market value is due to good size and attractive color. Both Peach and Apricot are highly sensitive to weather anomalies. It requires certain amount of chilling hour for its metabolic activities to start the reproductive phase. Slight fluctuation in diurnal temperature during a week will affect the bud break significantly. Dust storm/ hail storm during March- April, may affect the yield or fruit quality depending on the incidence. Increase in temperature can effect the ripening stage and also the post harvest management practices.

  - **Weather sensitive farm operation and crop growth stages**

Stone Fruits: Apricot/Peach	**Standard Met. Week ***	**Important weather parameter related to respective crop growth stage**	**Effect of weather parameter on Plant**
Dormancy Stage	40-6/ 40-6	RF. ,Temp, (min/max) & Humidity	Positive relationship if favorable Highly negative / not favorable
Bud Break	7/ 9	Temperature (Max.Min), RH morning and evening.	if favorable then 80% bud break if unfavorable 40-50% only.
Flowering	8-9/ 9-10	Rainfall temperature (Max.Min) Wind Speed	80% flowering if favorable decrease is one of the factor is unfavorable
Fruit setting	9-10/ 10-12	Temperature Wind Rainfall	100% if all favorable decrease is one of the factor is unfavorable
Fruit development	10-17/ 15-18	Temperature Sunshine hours Weather anomalies (hills storms and dust storm etc.)	fruit development depend on the weather anomalies
Fruit maturity	19-20/ 27-28	Temperature Wind Speed Sunshine hours	Positive is favorable negative if one of the factor is unfavorable

* For Standard Meteorological Week see Annexure-II

- **Measuring the impact of AAS**

Station: Solan

Station	Crop	Impact of AAS on cost of cultivation	Impact of AAS on gross returns	Impact of AAS on net returns	Impact of AAS on yield
Solan	Peach	Increase by 15.65%	Increase by 57.22%	Increase by 59.86%	Increase by 12.25%
Solan	Apricot	Increase by 2.18%	Increase by 76.26%	Increase by 82.64%	Increase by 23.65%

- **Overall analysis of the results obtained in terms of use of weather based AAS**

Input	**Amount of input used**		**Difference in yield due to input (Q/acre)**			**Difference in cost of cultivation (Rs/acre)**		
	AAS	**Non AAS**	**AAS**	**Non AAS**	**Diff**	**AAS**	**Non AAS**	**Diff**
Peach								
FYM (kg/acre)	909	1100	107	85	22	18790	11973	6817
Fertilizer kg/acre)	31	24						
Pesticide (kg/acre)	0	0						
Human labour (mandays/ acre)	26	23						
Irrigation (no:/farmer)	0	0						
Apricot								
FYM (kg/acre)	602	704	30	24	6	2805	2745	60
Fertilizer kg/acre)	17	22						
Pesticide (kg/acre)	0	0						
Human labour (mandays/acre)	14	12						
Irrigation (no:/farmer)	0	0						

6. Survey results on "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. The AAS service being run by NCMRWF has gained in popularity and reliability in the last 10-15 years of its existence. The AAS farmers are very receptive to the agro advisory being given to them and have also shown confidence in the weather forecast by accepting the advise free of cost and implementing the advice. The farmers in the process have also accrued substantial benefits from the service. So it was pertinent to assess through this survey the willingness of the farmers to pay for the service.

Therefore the survey also included a specific question about the farmers willingness to pay. Though the reply to this particular question was neither forthcoming nor overwhelming yet it definitely helped in analyzing the effectiveness and worthiness of weather forecast and also the risk taking ability of the sample farmers. Certain situations under which a farmer is ready to pay are

1. expected weather induced losses
2. risk taking ability of farmer (income & assets)
3. reliability of forecast

Though most of the AAS farmers in majority of the units were still not ready to pay and were willing to implement the weather based advisories on free of cost basis, yet there was a small group of farmers in Jaipur, Hyderabad, and Pune who gave their willingness to pay for the service. This small group of farmers possess medium to large land holdings. They generally cultivate cash crops and are ready to pay for the service if the price is nominal and service is specific to their needs. The small land holding farmers are unwilling to pay as they are generally poor and take huge loans against their holding and so do not have the risk taking ability. Although the farmers have gained confidence in the reliability of weather forecast, they still depend on their traditional methods of farming and rely more on superstitions rather than science.

7. Summary

For the last 15 years, NCMRWF has been providing forecast of different weather elements like maximum temperature, minimum temperature, cloud cover, rainfall, wind speed and wind direction twice a week (Tuesday and Friday) valid for subsequent four days. Using the Medium Range Weather Forecast, Agromet advisories are prepared and disseminated to the farmers of the AAS category in selected villages and feed back is collected to study the impact of advisories issued on various crops.

The project “Economic Impact Assessment of AAS of NCMRWF” was given to 15 AAS units in different agro-climatic zones of the country to assess the impact of the Agromet Advisory Services and to study the impact assessment frame work of AAS to make it more effective and efficient. Two villages each under AAS and Non AAS categories were selected and agro-advisories were issued based on Medium Range Weather Forecast provided by NCMRWF. In each village, four crops were chosen (two each during Kharif and Rabi seasons). Farmer awareness campaigns were organized from

time to time to create awareness on application of medium range weather forecast in minimizing risk in crop loss due to weather. The project is summarized below based on the detailed analysis of results indicating contributions made towards increasing the state of knowledge in the subject.

- The impact studies have created awareness among the farmers on the utility of Medium Range Weather Forecast.
- The impact study carried out included survey of traditional methods used by the AAS farmers in carrying out farm management practices. The traditional methods include observing stars, consulting Panchang, folklores and others for giving the forecast for wind speed, wind direction, rainfall, temperature, and cloud cover. Thus local inhabitants of the study area also use traditional ethos and wisdom for assessing weather forecast. This traditional technology has been developed through experience gathered over generations.
- A detailed analysis has been made about different socio-economic and other ecological determinants so as to have an idea about the willingness and capabilities of the farmers to pay for the agro-meteorological forecasts. It was seen that this depended on the risk taking ability of a farmer. Only those farmers who are prosperous are ready to take this risk and also pay for the advisory
- The study also highlights that majority of the AAS farmers are in the middle aged group and are atleast matriculate. The adoption level of any technological innovation depends to a larger extent on the educational level of adopters/respondents. It has been observed that educated respondents are easy to be targeted and sensitized about the benefits of new farms techniques based on agro-met advisory.
- The reliability of the forecast in terms of its usability to the adopters was also seen. It is seen that the forecasts are generally more reliable during Rabi season when compared to Kharif season. The reliability of rain forecast during Kharif season needs to be improved.
- The impact assessment framework also dealt with estimating the direct impact of the Agro-Advisory service on cost of cultivation, gross net returns and impact on yield. Crops selected included cereals, millets, oil seeds, cash crops, fruits and vegetables. The overall analysis in terms of percentage of increase in yield and total input cost is given in the Table 7.1 below

Table 7.1. Impact of the AAS service during the study period

Category	Crop	Station	Impact of AAS on cost of cultivation (Rs/acre)	Impact of AAS on gross returns (Rs/acre)	Impact of AAS on net returns (Rs/acre)	Impact of AAS on yield (Q/acre)
Cereals	Paddy	Raipur; Thrissur; Kalyani; Ludhiana; Bhubaneshwar; Hyderabad; Pantnagar	Decrease by 5-12%	Increase by 8-20%	Increase by 16-20%	Increase by 8-20%
	Wheat	Raipur; Ludhiana; Jaipur; Pune; Pantnagar	Decrease by 1-2%	Increase by 8-13%	Increase by 12-28%	Increase by 7-30%
Millets	Pearlmillet	Jodhpur, Jaipur, Pune	Increase by 1-5%	Increase by 4-14%	Increase by 10-28%	Increase by 4-25%
Vegetables	Tomato	Bhubaneshwar; Bangalore; Coimbatore; Hyderabad; Solan	Decrease by 2-5%	Increase by 7-20%	Increase by 12-30%	Increase by 13-23%
	Palak	Hyderabad	Decrease by 9.4%	Increase by 24.6%	Increase by 25.1	Increase by 24.4%
	Capsicum	Solan	Increase by 2.2%	Increase by 57.3%	Increase by 61.3%	Increase by 20.1%
	Onion	Pune	Increase by 0.9%	Increase by 20.4%	Increase by 30.1%	Increase by 30.2%
	Potato	Anand	Decrease by 3.1%	Increase by 10.3%	Increase by 13.5%	Increase by 5.4%
Cash Crops	Cotton	Hisar, Coimbatore, Hyderabad	Decrease by 4-10%	Increase by 2-3%	Increase by 6-20%	Increase by 3-20%
	Jute	Kalyani	Decrease by 24.9%	Increase by 11%	Increase by 21%	Increase by 14.1%
	Tobacco	Anand	Increase by 2.8 %	Increase by 11.7%	Increase by 21.5 %	Increase by 0.9%
Oil Seeds	Mustard	Hisar; Kalyani; Jodhpur	Decrease by 2-10%	Increase by 3-11%	Increase by 7-20%	Increase by 2-10%
Pulses	Gram	Raipur, Jaipur	Decrease by 3-5%	Increase by 8-14%	Increase by 11-30%	Increase by 7-16%
	Red Gram/ Tur	Bangalore	Decrease by 14.1%	Increase by 14.8%	Increase by 32.7%	Increase by 14.8%
Fruits	Banana	Thrissur, Coimbatore	Increase by 4-10%	Increase by 4-13%	Increase by 25-30%	Increase by 10-11%
	Peach	Solan	Increase by 10.6%	Increase by 57.2%	Increase by 59.9%	Increase by 12.3%
	Apricot	Solan	Increase by 2.2%	Increase by 76.3%	Increase by 82.6%	Increase by 23.7%

The above table attempts to isolate the 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 for the representative sample of users, there is ample scope for not catching holistic impacts. Considering the complexity of the situation one can understand the difficulty in estimating and quantifying the user response. Nevertheless, survey results as given in the Table 7.1 do provide credible information about the value of forecast-cum-advisory products.

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 by 5-10%. This shows that the right selection of fertilizers and seeds due to organization of awareness programmes in the villages and spraying of appropriate pesticides due to advisory saved the input costs. It is also observed that the yield increased by almost 10-25% in most of the crops with maximum increase in the fruit crops. Undertaking timely field operations due to adoption of agro-advisories being disseminated twice a week helped in improvement in the yields of various crops.

Besides the economic gains incurred by the user community through various strategies to mitigate the weather induced losses, the project also helped in creating comprehensive knowledge base on the following aspects:

- Prevalent weather and climatic conditions in the study zone
- Soil types in the agroclimatic zone
- Land topography in the area
- Socio-economic status of
    - farmers
    - farm labourers
- Crop yield in relation to national average and their growth potential
- Shifting of cultivation from traditional to modern methods of agriculture

8. Other accomplishments of the study

The Agricultural Advisory Services (AAS) program of NCMRWF is an innovative inter- departmental extension service, with a goal to deliver weather wise management of agriculture. Although an initial evaluation of AAS has been quite favourable, these evaluations have been quantitative in nature and are based on descriptive analyses of results of structured surveys. Hence more work needs to be carried out.

Based on observed differences across the AAS and non-AAS farmers, it appears that the AAS program is having substantial positive impacts on the availability and quality of advisory services provided to farmers, promoting adoption and use of modern agricultural production technologies and practices. AAS also appears to have promoted 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 yield obtained by AAS and non-AAS farmers for some crops. AAS appears to be having more success in promoting adoption of improved

varieties of crops and some other yield enhancing technologies rather than in promoting improved soil fertility management. Shortage of capital was often cited by farmers as a critical constraint facing them, in addition to shortage of irrigation water, lack of adequate farmland, unfavorable weather patterns and problems of pests and diseases. These 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. In general the areas in which the study has gained substantial accomplishments are

The study has helped to

- Increase awareness among farmers about the adoption of weather based advisory.
- Further improve the assessment of economic impact Agro advisory services on farm decision making
- Enhance the capacity of the farming community to take weather based farm management decision related to weather sensitive operations.
- Upgrade the existing knowledge of farmers as well as scientists on identification of
    - weather sensitive crops
    - weather sensitive stages of different crops
    - weather sensitive farm operations
- Develop standard methodology for assessing the economic impact of AAS services

9. Limitations of the study

One of the major limitation that makes the connection between accuracy of weather forecast and value of such forecast based advice, so difficult to define, is the cost/loss ratio. That is, if the user of a forecast takes some action in response to the forecast, that action has a cost. If the user fails to take that action, however, there may be a loss associated with that failure to act. A simple example is of a user growing crops that are sensitive to freezing. There are actions that the user can take (e.g., spraying fruit trees with water) to diminish the threat of freezing weather. These actions have a cost that a grower would not want to incur needlessly. However, failing to take those actions in a freeze means some amount of crop loss, creating a proportionate loss of income. Every user of weather information has a cost/loss ratio and, generally speaking, that ratio differs for each user. Some users are not knowledgeable about their cost/loss ratio and so are handicapped in determining whether to take a protective action.

Also in certain situations the costs and losses are very sensitive to weather, but not very sensitive to the weather forecast as in case of the hailstorm. The hail can cause tremendous crop losses, but there is very little a farmer can do to save the crops from its fury. A farmer might not be able to protect the crops, but investing in crop hail nets (or insurance) is a decision that must be made which is not particularly sensitive to the accuracy of forecasts but depends on climatology of the hail.

Even when cost/loss is known, however, Murphy and Ehrendorfer (1987) have noted that it is still difficult to be precise about the relationship between accuracy and value. They point out that it is typically possible to obtain a single-valued relationship

between accuracy and quality only when making a number of simplifying assumptions about the problem. Of particular importance is the process by which forecast accuracy is specified; generally, this is not completely determined by single scalar measures of accuracy.

While the study was designed and conducted in the most impartial way, yet, there is a possibility that some unexpected but unavoidable bias might have percolated into the survey. Some of them are listed below. Although these shortfalls/ deficiencies are obvious and expected in such types of surveys and due efforts are made to avoid these, yet some of them might have influenced the final results. A few of them are listed below.

- Surveyor bias- the sample survey is not independently conducted by the agency which provided the questionnaire leading to bias.
- sampling bias
- mutually exclusive set of AAS and non-AAS farmers regarding their awareness about weather based agro advisories
- partial incorrect information collected during survey
- Willfully concealing information about the actual benefits accrued by the farmer
- Fictitious information regarding the losses suffered on account of weather, for want of funds from government.

10. Scope for future work

Acceptance and use of weather information based farm advisories is likely to occur gradually. Farmers need time to try out new information, experience the benefits, and accept the results. Technology is changing rapidly whereas the mindset of the farmers changes slowly. Experiencing accurate information and beneficial outcomes leads to trust building which certainly will encourage educated farmers to adopt the advisories.

The following points may be taken into consideration while planning the future studies.

- Need to make these impact studies an integral part of the Agro advisory services of the country.
- Need to develop AAS service based decision support system for managing weather variability in reducing the negative impacts on yield.
- Improving package of practices for major crops keeping in view the weather sensitive crop stages and weather sensitive farm operations for reducing cost of cultivation and improving yield and increasing net returns.
- Need to improve the forecast quality during the sowing operations of kharif crops.
- Studies may be undertaken to quantify the value of medium range weather forecast in Nitrogen fertilizer management in arable crops. The N fertilizer advice may be tested through determining the uptake efficiency. The changes in N leaching, de-nitrification and crop N uptake due to the forecast quality needs to be assessed. Yield and gross profit changes may then be linked to N uptake.

- Need to integrate Medium Range Weather Forecast with extended range forecast for better planning of the field operations particularly for sowing and mid-season corrections incase of drought
- The impact studies should be replicated in other crops of the region.
- Similar studies are also needed in other AAS units in India.
- The successful implementation of the scientific agro-meteorological forecasts need blending with local technologies like traditional methods so that farmers can readily adopt and be benefited from these scientific forecast.
- There is need to deliver district level weather based advisories through an automated dissemination system.

In addition to the agriculture sector there is need to carry out similar studies in other weather sensitive sectors of economy as systematic and reliable data on the scope and dimensions of the relationship of weather and various user sectors is lacking. Better understanding of use and value of weather forecast may help substantially reduce the risks to life and property. For example, if there is knowledge about how many people and how much property is actually at risk to floods, one may be able to develop better strategies to reduce that undefined risk. In addition to the general lack of knowledge of the societal context of weather events, there is also limited understanding of how decision makers could and actually use weather information. The significance of this study seems to call for a wide range of interests to support the similar efforts on other sectors such as aviation, power etc. The power firms like the Power Grid Corporation of India (PGCIL) require location specific quantitative forecast of Maximum/ Minimum Temperatures, Rainfall, Clouds, Wind Speed/direction four days in advance to run their Load Forecast models and the Power Distribution models. PGCIL estimates about 5-12 % saving on power equivalent to Rs 110 crore per month through use of weather forecast of higher accuracy (>70%)

Therefore to undertake work in such spheres, there is urgent need to form a cohesive group of meteorologists (forecasters and researchers), users, and representatives from related fields (economics, policy makers, etc.). Although the entire meteorological community ought to be concerned with the outcome of that decision-making process, one should not try to do this in meteorological terms only. Public policy-makers must make difficult economic decisions that include issues of human safety, as well as purely economic factors. Decision making in weather sensitive sectors of economy must be made with knowledge of the economic impacts of weather forecasts, rather than without that quantitative information.

References

Das Gupta, M. and Rizvi, S. R. H. (2001): An Overview of Meteorological Data Decoding and Pre-processing Operational at NCMRWF, NCMRWF Tech. Rep. No: NMRF/TR/1/2001, 33pp.

Katz, R.W. and A.H. Murphy, 1997: Economic Value of Weather and Climate Forecasts. Cambridge University Press, 222 pp,

Kumar A, Parvinder Maini, Rathore,L.S. and S.V.Singh, 2000: An operational medium range local weather forecasting system developed in India *Int. J. Climatol*.**, (**a journal of Royal Meteorological Society), **20:** 73-87.

Maini Parvinder, Ashok Kumar, S.V.Singh and L.S.Rathore, 2004: Operational Model for Forecasting Location Specific Quantitative Precipitation and Probability Of Precipitation over India. *Journal of Hydrol*, **288**, 170-188.

Maini Parvinder, 2006: Development of Statistical-Dynamical Models for Location Specific Weather Forecast. (PhD Thesis), Andhra University, 242pp.

Murphy, A. H and M. Ehrendorfer, 1987: On the relationship between the accuracy and value of forecasts in the cost-loss ratio situation. *Wea. Forecasting*, **2**, 243-251.

NCMRWF/DST, Govt. of India, 1999: *Guide for Agrometeorological Advisory Service*". Govt of India Publication, 201pp (Eds: S.V. Singh, L.S.Rathore, H.K.N.Trivedi), Published by NCMRWF (DST), Mausam Bhavan, Lodi Road, N.Delhi-110003

NCMRWF/DST, Govt. of India, 2004: Monsoon-2004: Progress, Performance Prediction and Agro-Meteorological Advisories 197 pp, (Eds: AK Gupta, KK Singh, AK Baxla, JV Singh, R Singh) Published by NCMRWF (DST), A-50 Institutional Area, Sector-62, NOIDA,UP,INDIA 201307

NCMRWF/DST, Govt. of India, 2006: Monsoon-2005: Performance of the NCMRWF Global Assimilation Forecast System," 139 pp, Published by NCMRWF (DST), A-50 Institutional Area, Sector-62, NOIDA,UP,INDIA 201307

NCMRWF/MoES, Govt. of India, 2006: Monsoon-2006: Performance of the NCMRWF Global Assimilation Forecast System," 115 pp, Published by NCMRWF (MoES), A-50 Institutional Area, Sector-62, NOIDA,UP,INDIA 201307

Nicholls, J.M. 1996: "Economic and Social Benefits of Climatological Information and Services: a Review of Existing Assessments." World Meteorological Organization, Geneva, Switzerland. WMO/TD-No. 780. 38 pp.

Annexure-I

Following are the verification scores that have been used for verifying the rainfall and temperature forecasts disseminated to the AAS units on a bi-weekly basis

(a) Measures of obtaining skill of Yes/No rainfall

In the following 2×2 contingency table, if Y stands for occurrence of rain and N stands for non-occurrence then

Forecast (Rain)	Observed (Rain)	
	Yes	No
Yes	*YY*	*YN*
No	*NY*	*NN*

The total number of cases (*M*) is given by:

$$M = YY+YN+NY+NN$$

i. Ratio Score

Ratio Score (*RS*), also known as the Hit Rate or Percentage Correct, measures the proportion of correct forecasts. The *RS* varies from 0 to 100 with 100 indicating perfect forecasts.

$$RS = \frac{correct\ forecasts}{total\ forecasts} = \frac{(YY + NN)}{M} \times 100$$

ii. Hanssen and Kuipers' Score

Hanssen and Kuipers' Score (*HKS*) (Woodcock, 1976, 1981) is the ratio of economic saving over climatology due to the forecast to that of a set of perfect forecasts. In *HKS* the reference hit rate in the denominator is for random forecasts that are constrained to be unbiased.

$$HKS = \frac{correct\ forecast - (correct\ forecast)_{\text{random}}}{M - (correct\ forecast)_{\text{random, unbiased}}}$$

$$HKS = \frac{(YY * NN - YN * NY)}{(YY + NY)(YN + NN)}$$

That is, the imagined random reference forecasts in the denominator have a marginal distribution that is equal to the (sample) climatology (Wilks, 1995).The value of *HKS* varies from −1 to +1. If all forecast are wrong (i.e. $YY = NN = 0$) then it is −1, and if all forecast are perfect (i.e. $YN = NY = 0$) then it is +1, and random forecasts receive a score of 0.

(b) Criteria for obtaining usability of Quantitative Precipitation (QP)

Error Structure for verification of Quantitative Precipitation

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

where Diff stands for Absolute difference of observed and forecasted in mm and obs stands for observed rainfall in mm

(c) Measures of obtaining skill of temperature

Correlation Coefficient (*r*) and Root Mean Square Error (*RMSE*) are calculated for obtaining the skill of the model in forecasting maximum and minimum temperatures.

(i) Correlation coefficient can be defined as

$$r(f_i, o_i) = \frac{\sum (f_i - \bar{f})(o_i - \bar{o})}{\left[\sum (f_i - \bar{f})^2 \sum (o_i - \bar{o})^2\right]^{1/2}}$$

(ii) Root Mean Square Error (*RMSE*)**:** The *RMSE* is the square root of Mean Square Error (*MSE)* which measures the degree of correspondence between the forecasts and observations in terms of the average squared difference between f_i and o_i.

Where $$RMSE = \left(\frac{1}{n} \sum (f_i - o_i)^2 \right)^{1/2}$$

f_i = *forecast value*

$\bar{f}$ = *mean forecast value*

o_i = *observed value*

$\bar{o}$ = *mean observed alue*

n = *total no : of observations / forecast*

(d) Criteria for obtaining usability of Temperature forecast

Error Structure for verification of Temperature Forecast

Correct	$Diff \leq 1^0C$
Usable	$1^0C < Diff \leq 2^0C$
Unusable	$Diff > 2^0C$

where Diff stands for Absolute difference of observed and forecasted temperatures in ^0C

Annexure -II

Standard Meteorological Week Table

Wk. No.	Month	Dates	Wk. No.	Month	Dates
1	January	1-7	27	July	2-8
2		8-14	28		9-15
3		15-21	29		16-22
4		22-28	30		23-29
5		29-4	31		30-5
6	February	5-11	32	August	6-12
7		12-18	33		13-19
8		19-25	34		20-26
9		26-4*	35		27-2
10	March	5-11	36	September	3-9
11		12-18	37		10-16
12		19-25	38		17-23
13		26-1	39		24-30
14	April	2-8	40	October	1-7
15		9-15	41		8-14
16		16-22	42		15-21
17		23-29	43		22-28
18		30-6	44		29-4
19	May	7-13	45	November	5-11
20		14-20	46		12-18
21		21-27	47		19-25
22		28-3	48		26-2
23	June	4-10	49	December	3-9
24		11-17	50		10-16
25		18-24	51		17-23
26		25-1	52		24-31≠

***** In the leap year the week no. 9 will be 26 February to 4 March, i.e. 8 days instead of 7

≠ Last week will have 8 days, 24 to 31 December.