# Economic impact of the agro meteorological advisory services of Ministry of Earth Sciences - A review

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**सार** – सामाजिक, आर्थिक और पर्यावरणीय लाभों के लिए ESSO-MOES मौसम, जलवायु और आपदाकारी घटनाओं के पूर्वानुमान में सुधार लाने हेतु निरंतर प्रयास कर रहा है। इस उद्देश्य के लिए ये ढाँचागत विकास, तकनीकी ज्ञान के उन्नयन तथा मानव संसाधन विकास पर बड़ी मात्रा में निवेश कर रहा है। इन नई तकनीकी क्षमताओं से काफी बेहतर पूर्वानुमान और विश्वसनीय सेवा प्रदान करना निश्चित है। देश में हाल ही में घटने वाली मौसम की चरम घटनाओं के कुशल पूर्वानुमानों के माध्यम से यह बात साबित हो चुकी है। तथापि इन सेवाओं के आर्थिक लाभों का मूल्यांकन करके इस व्यय को उचित साबित करना महत्वपूर्ण है। ESSO-MOES आर्थिक मामलों में दी जाने वाली सेवाओं के प्रभाव का मूल्यांकन और आर्थिक लाभों के संबंध में नियमित रूप से अध्ययन करता है। ESSO-MOES द्वारा प्रदान की जाने वाली कृषि मौसम परामर्श सेवा के प्रभाव का मूल्यांकन और विभिन्न चरणों में आर्थिक लाभ पर किए गए अध्ययन की समीक्षा इस शोध पत्र में की गई है। इन अध्ययनों से पता चला है कि पिछले कुछ वर्षों में समग्र आर्थिक लाभों, लोगों तक इसकी पहुँच और सेवा की सार्थकता में भारत सरकार द्वारा किए गए बड़े पैमाने पर निवेशों के परिणामस्वरूप बेहतर पूर्वानुमान के कारण निश्चित रूप से सुधार हुआ है।

**ABSTRACT.** ESSO-MoES is making constant efforts to improve prediction of weather, climate and hazardous events for societal, economic and environmental benefits. For this it is making huge investments in terms of infrastructure growth, up-gradation of technical knowledge and human resource development. These new technical capabilities offer the promise of much improved forecasts and reliable service and this has been established through some of the recent skilful predictions of extreme events that occurred over the country. However, it is important to justify the spending through evaluating the economic benefits of the services. ESSO-MoES, regularly undertakes studies to carry out the impact assessment and benefits of the services it renders in economic terms. This paper is a review of the studies carried out in various phases, involving impact assessment and economic benefit of the Agromet Advisory service being rendered by ESSO-MoES. The studies indicate that over the years there is a definite increase in the economic benefits with improvement in the , outreach and worthiness of the service which is direct fallout of improved weather predictions as a result of the huge investments being made by Government of India.

**Keywords** − Impact assessment, Economic benefits, Agromet advisory services.

## 1. Introduction

Weather and climate play a very important role in various sectors of society namely, agriculture, aviation, health, tourism, ocean state, fishery, disastrous weather events etc. Adverse weather can disrupt life and property and can badly affect the economy of a country. Therefore the importance of accurate and reliable weather and climate forecasts has been increasingly felt over the past few decades. In order to do this, considerable amount of investment is being made world over to generate resources necessary for providing accurate advance information of weather and climate namely observing platforms at various levels, state- of the art models, high performance computing and research manpower knowledgeable in the field etc.

In India, the Earth System Science Organization-Ministry of Earth Sciences (ESSO-MoES) was therefore instituted in mid-2006 with a focus on world class research to develop and improve capability to forecast weather, climate and hazard related phenomena and to explore Ocean Resources for societal, economic and environmental benefits. For this ESSO-MoES has established a network of dense observing systems both on land and sea that include automatic weather stations, rain gauges, radars, wind profiler, ocean buoys etc. In addition ESSO-MoES institutes have high performance computing

capability of 1peta flop capacity to develop and run state-of the art Numerical weather prediction (NWP) and climate models and to deliver accurate and reliable weather forecasts. ESSO-MoES is also investing in various capacity building programs to address the growing demand of manpower required for delivering its mandate.

India is an agrarian country with 80% of the GDP depending on agricultural output. One of the major mandates of ESSO-MoES is to provide weather based agro-advisories for the benefit of farming community. Although ESSO-IMD (India Meteorological Department) has been providing the Agromet Advisory Service (AAS) since the mid-seventies in qualitative terms to the meteorological centers located in the state capitals, yet these forecasts, provided one day in advance were inadequate for planning weather based agricultural practices because the lead-time needed for taking precautionary measures in agriculture is longer. Therefore there was a requirement to provide these services in the medium range scale at a location to enable the farmers to carry out various agricultural operations such as sowing of weather-sensitive high yielding varieties, need-based application of fertilizer, pesticides, insecticides, efficient irrigation, planning for harvest etc. As a result, the Agromet Advisory Service (AAS) based on medium range weather forecast was initiated in 1991 in 127 Agro-climatic zones of the country in a phased manner by the National Centre for Medium Range Weather Forecasting (NCMRWF), then under the Department of Science and Technology. Since 2006, NCMRWF has come under the Ministry of Earth Sciences (ESSO-NCMRWF). In 2006 with the formation of Ministry of Earth Sciences, the AAS having been successfully demonstrated by ESSO-NCMRWF was re-located at ESSO-IMD in 2007 for extending the service (in operational mode) to districts under these agro-climatic zones. It is now called the Integrated Agro-meteorological Advisory Service of ESSO-MoES.

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 (Katz and Murphy, 1997). An awareness of the economic value of agrometeorological information can be of significant assistance in selecting decision-making strategies in agriculture. In view of this, study on the impact of the AAS and its economic benefits have been carried out periodically to understand the strengths and weaknesses of the service. The paper is a review of study of the economic benefit and impact assessment of the AAS carried out in three phases over the past 10 years. While Phase I was carried out by ESSO-NCMRWF itself, phase II and III have been carried out by an independent body. The following sections present the assessment carried out

in economic terms during Phase I and Phase II. This is followed by some results of phase III carried out recently. The last section talks about the future scenarios and way forward.

## 2. Economic benefit and impact assessment of AAS – Phase I

### 2.1. *Agro advisory service at ESSO-NCMRWF*

The National Centre for Medium Range Weather Forecasting (NCMRWF) was established under Department of Science & Technology (DST) in 1988 by Government of India with a major objective to develop numerical weather prediction based medium range weather forecast and agrometeorological advisory services (AAS) for the farming community in India. The NCMRWF in collaboration with India Meteorological Department (IMD), Indian Council of Agricultural Research (ICAR) and State Agricultural Universities (SAUs) initiated, in 1991, quantitative medium range weather based Agro-Advisory Service (AAS) on experimental basis at the scale of agro-climatic zone with 5 Agro Met Field Units (AMFU), representing 5 agro-climatic zones of the country, NCMRWF/DST, 1999. The country is divided into 127 agro-climatic zones with each zone covering about 4-6 districts. Beginning with 5 units in 1991, AMFUs were established in all the 127 zones of the country, in a phased manner, by 2006. Each AMFU covered a few districts in each agro-climatic zone.

Weather forecasts were given by NCMRWF to AMFUs on biweekly basis (Tuesday and Friday). The forecast, in quantitative terms, was issued for six parameters *viz.*, cloud amount (okta), precipitation (mm), wind speed (kmph), wind direction (degree), maximum temperature (°C) and minimum temperature (°C) four days in advance. In addition, the cumulative weekly precipitation (mm) was also provided. To generate all this information a forecasting system was developed at NCMRWF, Kumar *et al.*, 2000; Maini *et al.*, 2004. The forecast thus generated was disseminated to the AMFUs through email, fax and telephone. The AMFU assisted by an advisory board consisting of agricultural scientists representing wide spectrum of agricultural disciplines prepared the AAS Bulletins for their zone. The Bulletin in addition to the weather information contained agro advisories for the farmers recommending them to undertake best practices to maintain crop yields and to minimize weather-induced losses. The AAS Bulletin was disseminated to farmers by mass media (TV, radio, newspapers) in vernacular language. In addition contact farmers in several villages were given this information by phone, post, poster and hand delivery, NCMRWF/DST, 1999.

**TABLE 1**

**Major crops considered under the study**

| Station | Crops considered under the project |
|---|---|
| Anand | Potato, Tobacco |
| Bangalore | Ragi, Redgram |
| Bhubaneshwar | Rice (direct sown & transplanted), Tomato |
| Hisar | Cotton, Mustard |
| Hyderabad | Rice, Tomato, Palak, Cotton |
| Jaipur | Pearl Millet, Wheat, Gram |
| Jodhpur | Pearl Millet, Mustard, Cumin |
| Kalyani | Rice (Boro&Aman), Jute, Mustard |
| Ludhiana | Rice, Wheat |
| Pantnagar | Rice, Wheat |
| Pune | Wheat, Pearl millet, Onion |
| Raipur | Rice, Wheat, Gram |
| Solan | Tomato, Capsicum, Peach, Apricot |
| Thrissur | Coconut, Banana , Rice (irrigated & rainfed) |

In order to assess the quality and skill of forecast, a verification mechanism was also introduced (Murphy and Daan, 1985). A detailed verification conducted at the end of each season showed that the skill of the rainfall forecast was around 90% during Rabi and 69% during Kharif, NCMRWF/DST, 2004, 2006, NCMRWF/MoES 2007. Similarly the Root Mean Square Error (RMSE) of the maximum and minimum temperatures was found to vary in the range of 2-3 °C and in general the RMSE of minimum temperature was found to be lower than that of the maximum temperature during both the seasons.

Once the outreach of the service 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 (Nichollas, 1996). Thus periodic feedback was obtained from the AAS units on the economic benefit of the service which indicated that the weather based advisories issued by NCMRWF had considerably helped farmers to form a response strategy based on the prognosticated weather conditions. Though these reports were intermittent and were carried out using different methodologies, yet they were sufficient to indicate the positive and far reaching impacts of the weather based AAS. After successfully operating the service for more than ten years, it was imperative that NCMRWF carried out the economic benefit and impact assessment of the AAS rendered by it. Therefore in 2003 NCMRWF in consultation with the National Centre for Agricultural Economics & Policy Research (NCAP)

undertook a pilot study in 15 of the 127 AAS units to evaluate the use and value of the service in economic terms. The detailed article can be found in Maini & Rathore, 2011. However highlights of the article are presented in this paper.

### 2.2. *Methodology*

The study was carried out at 15 AAS units covering 6 seasons comprising of 3 Kharif (summer) and 3 Rabi (winter) season during 2003-2007 (Rathore & Maini, 2008). The major crops chosen for the study included food grains, oilseeds, cash crops, fruit and vegetable crops. The sample set consisted of 80 farmers. 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). The farmers were selected based on their size of holding (small, medium, large), educational background, size of the family, types of crops grown.  Table 1 shows the names of the units along with the crops considered under the study.

The questionnaire by NCAP was designed to capture the level of adoption of the weather based advisories by the farmers and to assess the benefit/loss accrued by the farmer by following/not-following the advisory. Thus the survey included queries on adequacy, use and impact of the medium range weather forecasts and also covered queries on crucial weather sensitive operations such as dates of sowing, planting, harvesting, spraying, irrigation and tillage etc. Table 2 gives the 3 different indicators based on which information was collected

### 2.3. *Results*

The results obtained from 3 year study is detailed in the paper by Maini and Rathore, 2011. However, salient features are discussed here

(a) *Socio-economic survey*

Socio-economic data obtained from farmers in the 4 zones of the country *viz*., : North (Ludhiana, Hisar, Pantnagar, Solan); West (Jaipur, Jodhpur, Anand, Pune); East (Raipur, Nadia, Bhubaneshwar); and South (Bangalore, Hyderabad, Coimbatore, Thrissur) was inter-compared and it was found that most of the farmers belong to the middle level age group with the south having the oldest population (70%), 45-50% of farmers are  matriculate with some illiteracy existing in the east (0-8%); 12% of the farmers in the west have large land holding of 25 acres followed by 10% in the north and about 65% of the farmers in the south and east have  small land holdings of 2.5-5 acres.

**TABLE 2**

**Indicators for assessment of economic benefits**

| Approaches | Indicators |
|---|---|
| Socio- Economic Status | Family structure; literacy; size of land holding; cropping pattern; traditional methods used; (f) awareness of AAS; (g) mode of receipt of AAS; (h) weather parameters required ;(i) satisfaction from service (reliability, timely availability, expected benefits, frequency); (j) willingness to pay |
| Quantity analysis of inputs | Quantity of seed, fertilizer, pesticide; (b) number of labour (human, machine) ;(c) number of irrigations |
| Price analysis of inputs used | Price of seed, fertilizer, pesticide; (b) cost of labour (human, machine); (c) cost of irrigation; (d) cost of product/by product; (e) any other associated cost |

The survey on weather information indicated that radio and television remain the most popular sources of receiving the weather information with 60-70% of farmers getting information through this source. The study concluded that rainfall and temperature forecast in all temporal ranges was important and was required for various farm operations well in advance. About 60-70% of the farmers felt that the rainfall forecast and the temperature trends were reliable. The survey also included a specific question on willingness to pay to understand the effectiveness and worthiness of the weather forecast. Although most of the farmers were not willing to pay for the service, yet a small number investing in cash crops were ready to invest a nominal fee. The small land holding farmers with less risk taking ability were unwilling to pay.

(b)  *Quantity and price analysis survey*

The survey was conducted by the Nodal Officer in the AMFU in the area under his/her unit. The survey was scheduled to coincide with different weather sensitive farm operations like, land preparation, sowing, planting, irrigation scheduling, fertilizer applications, harvesting and post-harvesting operations. In order to assess the direct impact of the AAS on cost of cultivation, gross net returns and impact on yield, the questionnaire designed by NCAP included related questions on date on which the different farm level operations were undertaken and the corresponding remedial action taken/not taken by the farmer in view of the impending weather/advisory, cost of seed, cost of labour (machine/human), number of irrigations undertaken, fertilizers applied, harvest technology adopted and various other issues. The data collected over a period of 3 years for both Rabi and Kharif seasons was analyzed to obtain percentage of increase in yield, total input cost for each of the crop considered and benefit to cost (B:C) ratio (Rathore & Maini, 2008 and Maini & Rathore, 2011). In general the B:C ratio is higher for the AAS farmers when compared to the non-AAS farmers, though the variation is much less for cereal crops in the Terai region and higher for highly weather sensitive crops such as vegetable and fruit crops. It is also seen that the difference in the cost of cultivation is not much

between the AAS and non-AAS farmers who grow cash crops like jute, cotton and tobacco as both category of farmers are prosperous and have high risk taking capability and therefore follow the weather advisories carefully irrespective of whether they receive it from the AAS of ESSO-MoES service or not. In general, in quantitative terms, 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. Similarly the AAS service helped increase the yield by almost 10-15% in most of the crops with maximum benefit in the fruit crops. The total benefit was also statistically validated in Maini & Rathore, 2011 and it was found that the difference in the yield between the AAS and non-AAS farmers is statistically significant at 5% level of significance.

Thus, the 2010 study carried out by ESSO-NCMRWF not only brought the impact of the AAS but also helped in determining the usage pattern of AAS and identifying the strengths and weaknesses of the service. In general the study revealed 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, Rathore and Maini, 2008. One of the major achievements of the study was that it helped in increasing awareness among farmers about the adoption of weather based advisories and their positive impacts. The results thus obtained, motivated ESSO-IMD to extend the service to district level from an agro-climatic zone level. However one has to be cautious while analyzing the results of Phase-I, since the sample survey was not independently conducted by the agency which provided the questionnaire and therefore a certain amount of bias was inevitable. This is one of the limitations of the Phase-I.

**3.    Economic benefit and impact assessment of AAS – Phase II**

3.1.  *Agro advisory service at ESSO-IMD*

In 2006 with the formation of Ministry of Earth Sciences, the Agromet advisory service having been

successfully demonstrated by ESSO-NCMRWF was re-located at ESSO-IMD in 2007 for extending the service (in operational mode) to districts under the 127 agro-climatic zones. It is now called the Integrated Agro-metereological Advisory Service of ESSO-MoES.

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, and pesticide/herbicide application. To improve the reliability of forecast in all temporal and spatial scales, Government of India is spending huge amount of money to strengthen the observational network through deployment of a network of Doppler weather radars, automatic weather stations, high speed computers, wind profilers, and to modernize the ESSO-IMD. Investment in terms of infrastructure and trained manpower has also been made to improve the Numerical Weather Prediction (NWP) models by using higher resolution models, ensemble prediction and by employing better data assimilation techniques.

For issue of the weather based agro advisory service, ESSO-NCMRWF had been using the T-80 General Circulation model at a resolution of $1.5° \times 1.5°$. This was increased to a resolution of $0.5° \times 0.5°$ in 2007 with the operationalization of the T-254 model. With the re-location of AAS at ESSO-IMD, and in order to extend the AAS service to districts of the country, ESSO-IMD adopted the multi-model ensemble forecast (MME) technique for issue of the weather based agro advisory service in quantitative terms (Mitra *et al.*, 2011; Bhowmick & Durai, 2008).

ESSO-IMD has been issuing 5 days advance weather information in quantitative terms at district level since June 2008 at 612 districts for rainfall, maximum and minimum temperature, relative humidity, surface wind and cloud cover in quantitative terms. The rainfall forecast are generated through multi-model ensemble (MME) system making use of model outputs of state-of the-art Numerical Weather prediction (NWP) models from five leading centers, [Bhowmick and Durai (2010 & 2012)]. The five NWP models considered are: (*i*) National Centre for Medium Range Weather Forecasting (NCMRWF T-254), (*ii*) European Centre for Medium Range Weather Forecasting (ECMWF T-799), (*iii*) Japan Meteorological Agency (JMA T-959), (*iv*) United Kingdom Meteorological Office (UKMO), and (*v*) National Centre for Environmental Prediction Global Forecast\System (NCEP GFS T-382). The Multi-model ensemble technique as described in Bhowmick and Durai (2010 & 2012) are applied to the outputs from these models. The product

thus obtained is then disseminated to Regional Meteorological Centres and Meteorological Centres of ESSO-IMD located in different states for value addition. Subsequently the products are communicated to 127 AMFUs located at State Agriculture Universities (SAUs), institutes of Indian Council of Agriculture Research (ICAR), IIT etc for further dissemination to the districts under the agro-climatic zone.

Weather based Agromet Advisory Service (AAS) bulletins are prepared twice weekly and issued at district, state and national levels to cater to the needs of agricultural community at various levels. The bulletins include realised weather of the previous week and quantitative district level weather forecast for next 5 days in respect of rainfall, maximum temperature, minimum temperature, wind speed, wind direction, relative humidity and clouds as well as weekly cumulative rainfall forecast and crop specific advisories including field crops, horticultural crops and livestock. Presently this service is covering over 600 districts of the country. AAS advisories are disseminated through various modes of communication including mass and electronic media. In addition to multi-mode dissemination system, advisories are disseminated to the farming community through SMS and IVR (Interactive Voice Response Technology) through regional and state level Public Private Partnership with various service providers. At present 4.7 million farmers are receiving the advisory through SMS. These advisories are used for scheduling irrigation and application of fertilizers and pesticides (ESSO-MoES Annual report, 2012-13, 2013-14, 2014-15).

As the AAS had expanded from agro-climatic zone level to the district level, it was pertinent to know whether the expansion to micro-level had actually helped the agricultural sector and also whether the dissemination of the service at micro-scale of district level had actually been achieved and benefitted the farmers.

ESSO-MoES therefore entrusted the responsibility of estimating the economic benefits of the service to the National Council for Applied Economic Research (NCAER), an independent, non-profit economic policy research institute in India. The 2010 NCAER study aimed to estimate the economic benefits of the services provided by the ESSO-MoES as well as realised benefits by beneficiaries, and their perceptions of the reliability and utility of such services. The period under the study was chosen as 2009-10. Among the various services chosen for the study, the agro-meteorological advisory services were a major one. The following sections describe the data used, methodology chosen and results obtained which have been detailed in a report published by NCAER, 2010.

3.2.  *Data and methodology*

(a)  *Approach*

There are a number of different techniques available to estimate the economic benefits of meteorological services. These include: (*i*) using 'market prices' to measure the benefits of 'private good' meteorological services; (*ii*) normative or prescriptive decision-making models; (*iii*) descriptive behavioural response studies including user surveys and regression models; (*iv*) contingent valuation models; (*v*) conjoint analysis; (*vi*) and computable general equilibrium or economy-wide models. In recent years, a number of studies have attempted to estimate the economic benefits of various types of meteorological services using some of these techniques (Nicholls, 1996; Katz and Murphy, 1997; Anaman *et al.*, 1998 and Stern and Easterling, 1999). NCAER in its report has taken into consideration the advantage of each approach as well as the limitation with respect to the present study and chosen the approach to be followed.

The NCAER 2010 study adopted a combination of Normative (prescriptive) Decision Making Model and descriptive behavioural response. The former approach views meteorological information as a factor in the decision-making process that can be used by decision makers to reduce uncertainty. Assuming that the decision makers are members of the farming community, NCAER in the present study conducted survey on farmers and compared the similar socio-economic background both from target areas (where information flow is facilitated) as well as from control areas. "Anecdotal" reports, case studies, and user surveys are examples of the latter approach which uses "Focus Study Group" method of compiling/capturing qualitative information. The focus study groups were formed to analyse the descriptive decision making models to decide on the strategies adopted by farmers, crop-wise. Ultimately the profits that farmers can attribute to use of forecasts were surveyed. The benefits accrued by farmers were converted in terms of numeraire after conversion of financial benefits into economic values by using conversion factors.

(b)  *Survey methodology and research design*

The NCAER 2010 study used a descriptive research design that involved both quantitative and qualitative components of data collection. As part of the quantitative component, structured interviews were carried out, *i.e.*, both face-to-face and telephone interviews and the qualitative capsule included in-depth interviews and focus group discussions.

(c)  *Respondent group and study area*

The NCAER study was carried out in 12 states and 1 union territory, *viz.*, Punjab, Uttar Pradesh, Bihar, Uttarakhand, Madhya Pradesh, Rajasthan, Gujarat, Maharashtra, Assam, Andhra Pradesh, West Bengal, Tamil Nadu and Puducherry.

(d)  *Sampling design*

Considering the requirements and design of the study, different sampling procedures were adopted to select the respondents. NCAER selected two different sets of districts, *i.e.*, districts with AMFU and districts without AMFU. In total 20 districts were selected across nine states. From each state one district with AMFU and one district without AMFU were selected. For selection of villages and respondents, the same procedure was adopted in both sets of districts.

(e)  *Selection of villages*

For selection of villages, a list of villages within a distance of 30 km or less and 50 km or more from the district headquarters was prepared and one village from each category was selected using the simple random sampling technique. An attempt was made to cover the required number of respondents from the selected villages. In case of a short fall in the number of eligible respondents in the selected village, another village was selected using the same sampling technique. This process was adopted in each category until the desired sample size was achieved.

(f)  *Selection of respondents*

In each selected village, household with farmers were identified and 10 farmers were selected for interview using a simple random technique. Each selected village was divided into two segments with approximately equal number of households. The centre point of each segment was considered as the starting point. From this point, following the left-hand rule, five households were selected with farmers available for interview. In all around 400 respondents were interviewed to elicit relevant information. Besides household interviews in this segment, telephone interviews were also carried out. The database for telephone interviews was procured from Reuter Mobile Services (RMS) which disseminates weather-related information among farmers. This database was used as the sampling frame and 171 samples were selected through systematic random sampling.

**TABLE 3**

**Percentage of farmers by category of land holding**

| Categories | With AAS | Without AAS |
|---|---|---|
| Homestead land | 90.1 | 92.1 |
| Cultivated land owned | 66.8 | 60.4 |
| Land cultivated | 55.4 | 60.4 |
| Leased in land | 21.3 | 16.3 |
| Leased out land | 2.5 | 7.9 |
| Irrigated land | 46.5 | 49.0 |
| Rainfed land | 29.7 | 29.7 |
| Total | 202 | 202 |

*Note:* The total exceeds 100 due to multiple responses.
[*Source: NCAER, 2010 report*]

**TABLE 4**

**Distribution of farmers by irrigation sources (%)**

| Source of Irrigation | With AAS | Without AAS |
|---|---|---|
| Canal | 8.4 | 5.9 |
| Tube well | 57.4 | 64.4 |
| Well | 17.8 | 14.9 |
| River | 2.0 | 1.0 |
| Others | 11.9 | 7.9 |
| No response | 2.5 | 5.9 |
| Total N | 202 | 202 |

[*Source: NCAER, 2010 report*]

### 3.3.  *Results*

(a)  *Socio-economic survey*

NCAER conducted the social-economic survey on the profile of respondent and non-respondent farmers and their household characteristics. The various parameters used were (*i*) age (*ii*) education, (*iii*) land holding etc. The results as brought out in the NCAER Report, 2010 are presented here.

*Age* : The mean age of farmers in AMFU districts was 44 years, and 45 years in districts without AMFU. Two-fifth of the farmers in non-AMFU districts compared to 28% in AMFU districts were in the age group of 40 to 49 years. Gender-wise analysis shows that the majority of the farmers in the survey (94% in AMFU districts and 97% in non-AMFU districts) were male.

*Level of Education* : One-fourth of the farmers in AMFU districts and one-fifth in non-AMFU districts are illiterate. Nearly one-fifth of the farmers in both types of districts have completed their secondary level of education. One-tenth of the farmers in non-AMFU districts are graduates or more.

**TABLE 5**

**Housing characteristics of farmer households (%)**

| Categories | With AAS | Without AAS |
|---|---|---|
| **Ownership pattern** | | |
| Own house | 97.5 | 98.5 |
| Rented house | 1.0 | 0.5 |
| **Housing condition** | | |
| Kuchcha | 14.4 | 11.4 |
| Pucca | 40.6 | 52.5 |
| Semi-kuchcha | 22.3 | 11.4 |
| Semi-pucca | 21.8 | 23.3 |
| Polythene | 0.0 | 1.0 |
| **Drinking water arrangement** | | |
| Tap | 69.3 | 66.8 |
| Well | 18.3 | 9.9 |
| Pond | 1.0 | 3.5 |
| Government or other agencies | 6.4 | 12.4 |
| Total | 202 | 202 |

[*Source: NCAER, 2010 report*]

*Category of land holdings* : Table 3 gives the category of land holdings among farmers. The majority of the farmers in both types of districts had homestead land. Two-third of the farmers in AAS districts and three-fifth in non-AAS districts reported that they owned cultivated land. The percentage of farmers in both districts who leased the land is very low.

*Sources of irrigation* : The majority of the farmers reported that their main source of irrigation was tube wells - two-third (64%) in non-AAS districts and three-fifth (57%) in AAS districts. Farmers in both the districts also cited wells as another irrigation source (Table 4).

*Housing characteristics of farmers* : The findings on the housing characteristics of the household are presented in Table 5. The majority of the farmers own a house. Two-fifth of the farmers in AAS districts while more than half the farmers in non-AAS districts reported had a *pucca* house. Nearly half the farmers in each set of districts reported *pucca* toilets in the house. Two-third of the farmers (69% in AAS districts and 67% in non-AAS districts) reported taps as the drinking water arrangement.

(b)  *Use of weather information by farmers*

Availability of timely weather information enables farmers to plan their farm-level operations. This not only minimises costs and crop losses but also helps maximise profits or yield gains. These weather forecasts are useful in taking decisions about planting/harvesting dates, and investments in farm inputs such as irrigation, fertilisers,

| Source | With AMFU | Without AMFU |
|---|---|---|
| All India Radio | 12.2 | 32.0 |
| TV | 75.5 | 74.0 |
| KrishiDarshan | 44.9 | 50.0 |
| Newspaper | 59.2 | 32.0 |
| Bulletin | 6.1 | 4.0 |
| Mobile phone | 8.2 | 6.0 |
| Internet | 2.0 | 0.0 |
| Friends | 26.5 | 20.0 |
| Total | 49 | 50 |

*Note*: Total exceeds 100 due to multiple responses.

[*Source: NCAER, 2010 report*]

pesticides, herbicides, etc. The biggest beneficiaries are the small farmers with small-sized cultivable land whose agricultural output depends on the monsoon. Unreliable information regarding the monsoon could cause significant losses to the farming community. Based on various attributes considered, NCAER during its study of the AAS versus the non-AAS farmers concluded about the awareness and use of weather information during 2009-10, the year of study. One-fourth of farmers (25%) in each set of districts, *i.e*., districts with AMFU and districts without AMFU, reported the same. These are briefly discussed here.

*Sources of weather information* : Television was reported as the highest source among farmers in both districts: with AMFU (76%) and districts without AMFU (74%). Krishi Darshan was reported as the prime source of weather information by 45% by farmers in districts with AMFU and half the farmers in districts without AMFU. Newspapers as a source of information was reported by three-fifth (60%) of the farmers in districts with AMFU and one-third of the farmers in districts without AMFU (Table 6). Frequency of use of weather information among farmers shows that half of the farmers in districts with AMFU and four-fifth in districts without AMFU use the radio and television daily for getting weather information. Using Krishi Darshan daily was reported by one-third of the farmers in districts with AMFU compared to half the farmers in districts without AMFU.

*Operations where weather information is used* : Farmers in districts with AMFU use weather information in various farming operations which include sowing and harvesting (74%), spraying pesticides (71%), cropping patterns (59%), scheduling irrigation (53%) and fertiliser application (51%). Farmers in districts without AMFU

reported cropping patterns (84%), sowing and harvesting (76%), scheduling irrigation (69%) and spraying pesticides (63%) as the operations where weather information is used.

*Cost-benefit of weather information* : For each farming operation, the farmers in districts with and without AMFU were asked about the cost-benefit of weather information. The overall findings suggest that although there is not much difference in the overall cost benefit between the AAS and non-AAS farmers, weather forecast and information seem to make a very significant contribution in reducing cost and increasing income in different farming operations

*Importance of weather information in making profits* : Farmers in both AMFU and non-AMFU districts were asked whether they have used weather advisories for farm - level operations. Two-third (66%) of the farmers in districts with AMFU and half (51%) in non-AMFU districts reported using such advisories for farming. Those who reported so were asked whether the information they receive has helped them make profits in the past five years. About one-fourth (23%) of the farmers in districts with AMFU and one-fifth (19%) in districts without AMFU reported making profits in the past five years which highlights the contribution of AMF units.

*Value of weather information* : The farmers were asked to rate the weather information in terms of its helpfulness and reliability. The reliability of forecast was judged from the skill of the forecast in terms of lead time and accuracy, whereas the helpfulness was judged based on the decision taken on farm level operations such as sowing of seeds, irrigation scheduling, fertilizer application, harvesting etc. based on weather forecast. Nearly half the farmers in districts with AMFU and one-third in districts without AMFU agree that the weather information is helpful and reliable. This finding clearly highlights that AMFUs play an important role in providing valuable information to farmers. About one-fourth of the farmers from both sets of districts strongly agree that the weather information is helpful and reliable. One-tenth of the farmers in districts with AMFU and around 2 percent of the farmers in districts without AMFU reported that the weather information helped reduce costs during stress or other periods. This also highlights the importance of weather information in farming.

*Awareness of services* : Awareness of the bulletin of the Agro Advisory Services (AAS) being rendered by ESSO-IMD is very low among farmers in both sets of districts. Only 24% farmers were aware of the AAS. Less than one-tenth of the farmers reported being aware of individual interaction of AAS/other agencies or the Common Service Centre (CSC).

**TABLE 7**

**Preferred sources and areas of information (%)**

| Source | With AMFU | Without AMFU |
|---|---|---|
| Mobile | 42.9 | 50.0 |
| T.V | 14.3 | 12.5 |
| Radio | 16.3 | 10.0 |
| Bulletin | 2.0 | 0.0 |
| Newspaper | 18.4 | 17.5 |
| Any agency / agent/NGO | 0.0 | 2.5 |
| None/Nothing | 6.1 | 5.0 |
| Don't know/Can't say | 4.1 | 3.0 |
| **Areas of Operation** | | |
| About crops harvesting | 32.7 | 10.0 |
| About seeds and manure | 10.2 | 30.0 |
| About insecticides | 8.2 | 7.5 |
| Detailed information about agriculture | 38.8 | 25.0 |
| Information about rainfall | 4.1 | 10.0 |
| Market-related | 6.1 | 0.0 |
| New technology for agriculture | 0.0 | 5.0 |
| Scheduling irrigation | 0.0 | 5.0 |
| Don't know/ Can't say | 6.1 | 10.0 |
| Total N | 49 | 50 |

*Feedback on preferred source and area of weather information* : The preferred source of information is a mobile phone, which was reported by 43% of the farmers in districts with AMFU and half the farmers in districts without AMFU. Newspapers are another preferred source of information, reported by 18% of the farmers in each of the districts with and without AMFU. TV and radio are other sources as reported by farmers in both districts with and without AMFU.  The top areas of operation where the information is preferred include crop harvesting (33%) and more detailed information on agriculture (39%) by farmers in districts with AMFU, while farmers in districts without AMFU reported information on seeds and manure (30%) as vital and more detailed information on agriculture (25%). Table 7 gives the details.

*Farmers willing to pay more for information* :  One-fourth of the farmers in districts with AMFU and one-fifth in districts without AMFU reported their willingness to pay for receiving detailed weather information.

*Special survey on use of mobile phones by farmers* : As mobile phones  were  the most preferred choice of obtaining weather information, NCAER conducted special survey to study this aspect. 171 farmers were interviewed over the telephone to assess the usefulness of mobile phones in providing weather information. Farmers from
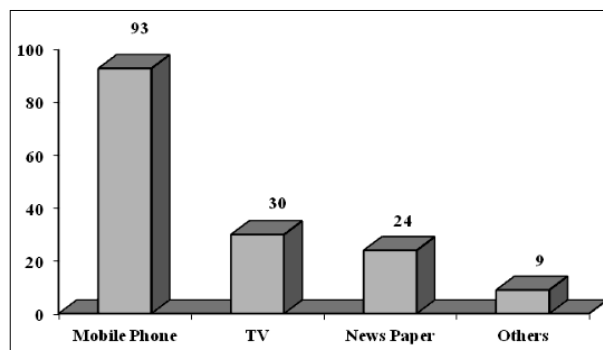


**Fig. 1.**   Farmers using different sources for weather information (%) [*Source* : NCAER, 2010 report]
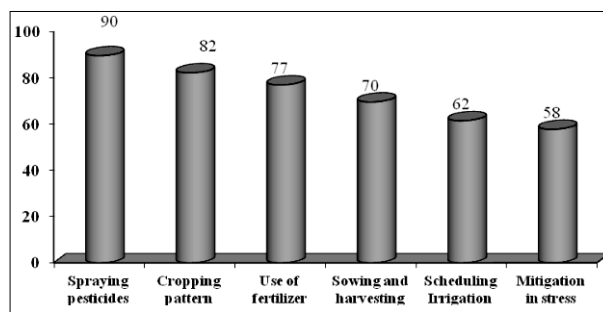


**Fig. 2.**   Type of information received through mobile phones [*Source* : NCAER, 2010 report]

Madhya Pradesh, Punjab, Uttar Pradesh, Gujarat and Maharashtra were interviewed over the telephone. As expected, among farmers who use mobile phones to get information on the weather, mobile phones are their main source of information. Besides mobile phones, about one-third (30%) also use television and about one-fourth (24%) depend on newspapers for weather information. Fig. 1 gives the detail information.

During the telephone interviews, it was found that on average, farmers have been using phones for the past one and half years for this service. About half the farmers (49%) have used mobiles for less than one year to receive weather information. About four-fifth (79%) of the farmers feel that the information provided over mobile is useful for their farming. Most of the information received is on spraying pesticides. More than three-fourth of the farmers also receive information on cropping patterns (82%) and use of fertilisers (77%) in farming.

Although the information is found to be useful, half the farmers were not ready to pay for additional information.  Fig. 2 gives the percentage of different type of information received.

**TABLE 8**

**Farmers' profit from the use of weather information**

| Crop | Average Profit in Rs./ton | Total Production (million tons) in 2009-10 | Farmers' Profit (Rs. crore) Scenario 1 (Awareness limited to 24% farmers) | Farmers' Profit (Rs. crore) Scenario 2 (Awareness limited to 50% farmers) | Farmers' Profit (Rs. crore) Scenario 3 (Awareness limited to 100% farmers) |
|---|---|---|---|---|---|
| Paddy | 6469 | 107.48 | 9679 | 20164 | 40329 |
| Wheat | 4971 | 80.58 | 5575 | 11615 | 23230 |
| Maize | 40363 | 12.61 | 7085 | 14760 | 29520 |
| Cotton | 46711 | 23.66 | 15384 | 32050 | 64100 |
| Gram | 8777 | 7.05 | 861 | 1794 | 3589 |
| Soya bean | 6465 | 8.93 | 804 | 1674 | 3348 |
| Jawar | 7000 | 2.55 | 248 | 518 | 1035 |
| Sugarcane | 402 | 249.48 | 1396 | 2909 | 5818 |
| Mustard | 20600 | 7.37 | 2113 | 4403 | 8806 |
| Bajra | 450 | 5.83 | 37 | 76 | 152 |
| Tobacco | 30000 | 0.49 | 205 | 426 | 853 |
| Groundnut | 14806 | 4.53 | 934 | 1945 | 3890 |
| Total | | | 44321 | 92335 | 184671 |

*Note*: Cotton production in million bales of 170 kg each. *Source: NCAER Report 2010*

(c)   *Calculation of economic benefits to farmers*

NCAER during its survey found that only 24% of the farmers are aware about the weather based agro advisories issued by ESSO-IMD. NCAER has also cited various reasons for the limited outreach. However NCAER in its study brought out economic benefits accrued under three scenarios when awareness is limited to (*i*) 24%, (*ii*) 50% and (*iii*) 100%.

**Scenario 1** : *Awareness limited to 24 per cent farmers*

Economic profit derived by farmers through the use of the weather information provided by the ESSO-IMD was calculated by NCAER during its survey. These are therefore the sample profit estimates. In the sample taken for the study, the economic benefit originating from the use of weather information by the farmers was calculated; 24% of the farmers had access to use of the weather and climate information forecasts.  All 24 percent who had access to information did not realise benefits. The NCAER survey found that of these farmers only 58% could make a profit from the information provided. "*Economic profit*" was calculated by NCAER with the help of the following formula:

*Economic benefit from the use of weather information = (% of farmers receiving weather information * % of farmers profiting from the information * average profit * cropwise attributable to weather information * total production of crop) * conversion factor)*

The conversion factor translates financial values to economic values by using the ratio of international prices to domestic prices for farm output (*Source* : NCAER 2010 Report).

Crops that were considered for the study were paddy, wheat, maize, cotton, gram, soya bean, jawar, sugarcane, mustard, bajra, tobacco and groundnut. Table 8 gives the financial profit of the farmers during 2009-10 under the three different scenarios. In the table,  total production figures reported by the farmers is in million tons for the year 2009-10, while average profit is reported in Rupees per ton. In scenario 1 when only 24% of the farmers are aware of the AAS, farmers financial profit through calculations comes to Rs.44321 crore.

**Scenario 2** : *If awareness increases to 50 per cent farmers*

The total farmers' financial profit will be Rs.92,335 crore when 50% of the farmers are aware of the weather information.

**Scenario 3** : *If awareness increases to 100 per cent Farmers*

If the awareness increases to 100% then the farmers' financial benefit will be Rs.1,84,671 crore.

**TABLE 9**

**Farmers' profit and economic profit from the use of weather information**

| Crop | Farmers' profit (Rs. crore) | | | Conversion factor | Economic profit (Rs. crore) | | |
|------|------------|------------|------------|-------------------|------------|------------|------------|
| | Scenario 1 | Scenario 2 | Scenario 3 | | Scenario 1 | Scenario 2 | Scenario 3 |
| Paddy | 9679 | 20164 | 40329 | 1.66 | 16087 | 33515 | 67031 |
| Wheat | 5575 | 11615 | 23230 | 1.00 | 5596 | 11658 | 23317 |
| Maize | 7085 | 14760 | 29520 | 0.95 | 6756 | 14075 | 28150 |
| Cotton | 15384 | 32050 | 64100 | 1.00 | 15384 | 32050 | 64100 |
| Gram | 861 | 1794 | 3589 | 1.00 | 861 | 1794 | 3589 |
| Soya bean | 804 | 1674 | 3348 | 1.46 | 1174 | 2447 | 4894 |
| Jawar | 248 | 518 | 1035 | 0.87 | 216 | 450 | 901 |
| Sugarcane | 1396 | 2909 | 5818 | 1.00 | 1396 | 2909 | 5818 |
| Mustard | 2113 | 4403 | 8806 | 1.00 | 2113 | 4403 | 8806 |
| Bajra | 37 | 76 | 152 | 1.00 | 37 | 76 | 152 |
| Tobacco | 205 | 426 | 853 | 1.00 | 205 | 426 | 853 |
| Groundnut | 934 | 1945 | 3890 | 1.00 | 934 | 1945 | 3890 |
| Total | 44321 | 92335 | 184671 | | 50760 | 105750 | 211499 |

Conversion Factor: Ratio of International price/ MSP;
*Source* : International Prices: World Bank and MSP : Directorate of Economic and Statistics, India. *Source : NCAER Report 2010*

Financial gains occurring to farmers can be attributed to accurate weather forecasts and the associated appropriate agro-advisory services. These financial gains to the farmers' community (considered a "reference group" in this study) have been converted to economic gains by NCAER using crop-wise conversion factors [ratio to international prices (World Bank) to MSP]. Table 9 gives the details.

It is seen from Table 9 that the economic profit estimates vary between Rs. 50,000 crore (where 24 per cent farmers receive weather information) to Rs.105, 750 crores (where 50 percent farmers receive weather information) to Rs.211,000 crore (where all farmers receive weather information). The table clearly brings out that the economic returns are quite sensitive to the proportion of farmers receiving information.

**4. Economic benefit and impact assessment of AAS – Phase III**

During the last 5 years, in addition to the R & D efforts, ESSO-MoES has invested considerably on improving the infrastructure and development of human resources necessary for providing skillful weather and climate forecast. Presently the High performance computing facility of ESSO-MoES units is 1.2 Petaflop against a mere 120 Teraflops in 2007.The Numerical weather prediction models which had a resolution of 50 kms in 2007 (T254) are now being run at a higher resolution of 25 kms (UK Met office Unified model) and

22 kms (T574). Enhancement of data for assimilation in the Analysis and Forecast System is the back bone for a reliable forecast from any NWP model. Considerable efforts have been made over the past few years to assimilate both conventional and non-conventional data including all new type of satellite observations into the model. The new satellite data include radiance and winds from METOP-B, OSCAT-25 km resolution winds, Meteosat-10 AMVS, CrIS and ATMS radiance, GEOS clear sky radiance, polar AMVs, GOES Imager (BT) (Annual Report 2013-14). In addition 14GB radar observations from 17 Indian radar stations have been received resulting in manifold increase in the total number of observations received and the total volume of data now being received is around 35GB/day (Annual Report 2014-15).

These efforts have helped to boost research in weather and climate forecasting and in general have resulted in improvement of skill of medium range forecasts by about 1 day as reported by Prasad *et al.,* 2014. In addition ESSO-NCMRWF is also running the ensemble prediction system with 32 members and is using this to give probabilistic forecast. These models have been successfully implemented at ESSO-IMD for use in their various services. Some of the classic examples of reliable forecast is the Hudhud cyclone that occurred in September 2013, the Uttarakhand floods in June 2013 and the Srinagar floods in September 2014. In addition, ESSO-MoES has invested considerably in capacity building programs through establishment of its own training

schools and granted extramural support for initiating post-graduate programs in the field of Earth Sciences. As a result of the enhancement in technical capabilities and with the added thrust given by ESSO-IMD to provide the AAS through mobile service, the number of farmers receiving the AAS has exponentially increased over the years and currently more than 4.5 million farmers receive the AAS through SMS. In view of the above, it became necessary to once again conduct an economic survey of the AAS being provided by ESSO-IMD.

NCAER was once again entrusted with the responsibility of carrying out the study with an aim to bring out the change in the perception of the Indian farmer, if any, about the reliability and advantages of weather forecast and to obtain the economic benefits accrued by the farmer as a result of improvement in service in terms of accuracy of weather forecast and outreach of the service crop-wise during both Kharif and Rabi season. The details can be found in the NCAER 2015 report. Some salient outcomes are mentioned in this review paper.

In this study, NCAER in partnership with Reliance Foundation carried out a limited survey of farmers covering 918 agricultural households across seven states in 35 districts. The sample set of Agricultural households was chosen based on the key indicators arrived at by the National Sample Survey Organisation (NSSO) under the Ministry of Statistics and Programme Implementation (MOSPI) in its survey carried out during the period June 2012-July 2013 for 70,000 agricultural households spread across 29 states and 7 Union Territories. This formed the sample basis to project net potential economic benefits, crop-wise, at the all-India level for the population of agricultural households estimated based on the unit level data of NSSO, which NCAER obtained for the exercise (herein after referred to as NSSO 2014 survey). The study of the limited survey revealed that

▪ The weather predictions help farmers in controlling farm expenses (seeds, fertilisers and plant protection chemicals application) and also help in increasing the net farm income.

▪ Ninety (90%) of the farmers, barring a few in Gujarat and Madhya Pradesh, feel reliability of weather forecast has improved over the past 2-4 years which is mainly attributed to the NWP model output given by ESSO-NCMRWF, 3-10 days in advance, to ESSO-IMD. In addition, the effectiveness of ESSO-IMD in timely dissemination of the weather based agro advisory through interface with NGOs and corporate has contributed significantly in raising awareness among the farming community. About 57% farmers felt that there is improvement in the timeliness of the weather forecasts.

▪ NCAER 2015 report has brought out that the use of weather prediction information of the ESSO-NCMRWF-IMD on 4 principal crops namely wheat, paddy, sugarcane and cotton can generate upto Rs.42,000 crores potential economic benefit annually and a net economic benefit of Rs 3.3 trillion (330,000 crores) over a useful life of 25 years . Similarly top 14 principal crops and top 20 principal crops can realise potential economic benefit annually at Rs.60,000 cr and Rs.67,000 cr respectively and fetch a potential economic benefit of Rs.4.7 trillion and Rs.5.2 trillion over a useful life of 25 years. The economic benefit is enormous compared to the mere Rs. 485 crores investment made by ESSO-NCMRWF.

▪ Thus the outcome of the report clearly brings out the improvement in weather forecast in terms of accuracy, reliability, and its utility in various farm level operations and the resultant economic benefits of the Agromet Advisory service over the past 4 years. This can be largely attributed to the concerted efforts made by ESSO-MoES in infrastructure and human resource development.

## 5. Recommendations and the way forward

NCAER in its report has observed that while ESSO-IMD provides district agro-meteorological information and advisory at five-day intervals, the services are grossly insufficient to meet the mounting challenge of weather change. NCAER has further brought out some of the key bottlenecks of the District Agromet Advisory Service (DAAS) of ESSO-IMD which include:

• Given that weather poses a massive challenge to Indian agriculture, at the policy level, more focus should be given to develop adequate agro-meteorological infrastructure in the country. With just about 130 Agro-Meteorological Field Units the agro-meteorological infrastructure in the country is extremely under-developed and needs extensive scale-up.

• At the level of information dissemination, while the provision of DAAS information is commendable, this needs to be at a more micro level (such as the mandal level) so as to make the information more precise and useful to the farmer. Further, AAS information published electronically by IMD reaches limited farmers due to insufficient Internet access.

• Research and development in agro-climatology is found wanting in applied research and farmer interaction. Private sector participation in institutional capacity building will be an added advantage.

• There is a need to develop a comprehensive policy and action plan that assesses various scenarios of the

possible impact of climate change on agriculture. Therefore key intervention is required by the policy makers in the following:

*Building specialised and dedicated institutional capacity for agro-meteorology* : There is an urgent need to build a dedicated national institution that is focused on developing infrastructure and information on weather risks to agriculture. Information thus generated needs to be efficiently used as adaptive responses to weather change by the farming community and all other actors involved in agriculture.

*Building a robust, scientific and intensive agro-meteorological infrastructure network* : This network will have the capability to capture weather information up to the mandal or taluk level. There is a need to promote ICT participation for transfer of information to the farmer. While the ESSO-IMD has invited proposals from public and private institutions in the media, telecom and IT sectors to take up the task of distributing agro-meteorology advisory to farmers, there is a need to bring in economically viable yet farmer-friendly public-private partnership models to efficiently disseminate weather information to the farmer. Presently ESSO-IMD is extensively using the mobile service to provide the DAAS to the farmers and currently 4.5 million farmers are benefitting from the mobile service.

*International collaboration* : In order to adopt the best practices available in the world to ensure maximum economic benefit, ESSO_IMD should collaborate with various international agencies to adopt technologies that can improve its agro-based advisory service in terms of input usage, different farm level operations and maximum output. There are many global technologies linking agro-meteorology to scientific yield management of crops. While the use of such technologies in India is limited at the individual farmer level, it could be introduced at a community or a village level through proper government support.

*Developing a focused and integrated R&D program for agro-climatology* : There is need for a pan-India detailed study of the crops and climate on a region-wise basis and efficient dissemination of this information to the farmer.

## 6.   Conclusions

During Phase-I, the study was carried out at selected AMFUs and with selected farmers. Although all efforts were made to select the sample through random sampling, yet there was every chance for bias to creep in as the nodal officers implementing the service were themselves responsible to collect the information detailed in the questionnaire. Nevertheless, phase-I gave a fair idea about the positive impacts of the AAS being rendered by ESSO-MoES. In fact it was observed that the survey conducted by NCAER during 2010 echoed some of the conclusion on socio-economic impact obtained in Phase-I.

While Phase-I presented the reduction in cost of cultivation and the net profit in terms of yield in percentage, Phase -II brought out the famers profit and the economic benefit in amount of rupees. Moreover the Phase-II carried out by an independent agency also brought out the lacunas existing in the system which enabled the ESSO-MoES to take corrective measure to improve the outreach of the service through use of modern technology.

Phase-III has once again established the usefulness of accurate weather prediction in agromet advisory service and has given a fair insight into the advantages a service can have due to significant improvement in technology as well as human resource development.

In addition there is need to develop Intra and inter institutional collaborations. ESSO-MoES is already making concerted efforts to bring in synergy within its constituent units through development of joint programs that involve different units of ESSO. During the 12th plan several new mission mode programs have been initiated that involve the expertise available with various centers of ESSO. For example the Monsoon mission program, System of Air Quality and Weather Forecasting And Research (SAFAR program, Severe Weather Forecast, Integrated water cycle program etc. While many institutions other than ESSO institutes such as the State Agricultural Universities, Indian Council of Agriculture Research (ICAR) and Indian Institute of Science (IISc) are engaged in research on agro-meteorology and weather forecasting, their efforts are rarely co-ordinated towards a common goal. There is a need to build strong cross-institutional interaction and develop co-ordinated research programmes amongst these institutions so as to leverage their combined strengths and offer robust weather forecasts for crops.

related information to NCAER for carrying out the study in Phase-II and Phase-III.

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