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Impact Assessment and Economic Benefits of Weather and Marine Services

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Preface

The Ministry of Earth Sciences (MoES) was formed in 2006 from a merger of the India Meteorological Department (IMD), the National Centre for Medium Range Weather Forecasting (NCMRWF), the Indian Institute of Tropical Meteorology (IITM), Pune, Earth Risk Evaluation Centre (EREC), and the Department of Ocean Development. The Mission of the MoES is to provide the nation with forecasts of the monsoons and other weather/climate parameters, and information about ocean state, earthquakes, tsunamis and other phenomena related to earth systems through well-integrated programs. These services have significant economic and social benefits that are otherwise very difficult to quantify. The actual and potential benefits to the key stakeholders like individuals, firms, industry sectors and national bodies from state-of-the-art meteorological and related services are substantial and, till today, they are inadequately recognised and insufficiently exploited in India.

NCAER was approached by the MoES to carry out a comprehensive study to understand the perspectives of the main stakeholders on the weather and marine services and estimate the economic and social benefits of these services provided by the MoES. However the MoES provides numerous services and the number of beneficiaries is large. This study has restricted to the main stakeholders, such as farmers and fishermen. The services chosen for this study were agro-meteorological advisory services, fishery services, tsunami warning services, severe weather warning services and public weather forecast services.

It was found that awareness on the utility of ocean state information and identification of Potential Fishing Zones (PFZs) among fishermen was quite high as provided by the Indian National Centre for Ocean Information Services (INCOIS). Identification of potential fishing zones increases productivity, significantly improves catch size and reduces fuel consumption while ocean state information is quite useful in timing departure and sequencing on shore activities and avoiding extreme weather-related emergency situations. The catalytic role played by the MS Swaminathan Research Foundation (MSSRF), the adoption of the 'Fishermen Friends' programme, and PFZs leveraging technology options such as Digital Display Boards with NGOs intermediation were seen as positive outcomes in the study.

In the case of farmers, only 24 percent were aware of weather information. Farmers' awareness of the bulletins of Agro Advisory Services on setting up common service centres was quite low. It is suggested that a Farmers' Friends Programme be replicated on a pilot scale along the lines of the Fishermen Friends Programme to institutionalise the NGO intermediation process in disseminating weather information to the farming community.

It is hoped that this study would be valuable to planners and policymakers in understanding the usability of national meteorological and ocean state services in the Indian context.

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Suman Bery
Director-General

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The comprehensive study of Impact Assessment and Economic Benefits of Weather and Marine Services within the specified time frame would not have been possible but for the cooperation of a number of people and orgainsations.

India Meteorological Department (IMD), Indian National Centre for Ocean Information Services (INCOIS) and MS Swaminathan Research Foundation (MSSRF), have put in a great deal of effort to give the study a final shape. The NCAER would therefore like to thank all those individuals who met its team members during the course of this study assigned by the Ministry of Earth Sciences and have worked towards the completion of this report. NCAER also takes this opportunity to thank Sigma Research and Consulting Pvt Ltd, the partnering research agency, for coordinating field survey, and the associated data collection, collation efforts etc in a very professional manner; the NCAER team was responsible for research and compilation of the report.

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Contents

List of Tables

List of Figures

List of Boxes and Map

Abbreviations

AASs	Agro Advisory Services
ACWSs	Area Cyclone Warning Centres
ADPC	Asian Disaster Preparedness Centre
AIR	All India Radio
AMDAR	Aircraft Meteorological Data Relay
AMFU	Agro Met Field Units
API	Antecedent Precipitation Index
AWSs	Automatic Weather Stations
BPRs	Bottom Pressure Recorders
CDO	Central Dense Overcast
CDRs	Cyclone Detection Radars
CIPS	Central Information and Processing System
CISN	California Integrated Seismic Network
CPUE	Catch Per Unit Effort
CS Pro	Census and Survey Processing
CSCs	Common Service Centres
CSO	Central Statistical Organisation
CWC	Central Water Commission
CWCs	Cyclone Warning Centres
CWDS	Cyclone Warning Dissemination System
CZCS	Coastal Zone Color Scanners
DAAS	District-level Agro-meteorological Advisory Service
DAOs	District Agriculture Offices
DCPCs	Data Collection and Production Centres
DIT	Department of Information Technology
ECA	Europe and Central Asia
EDBs	Electronic Display Boards
EEZ	Exclusive Economic Zone
ESCAP	Economic and Social Cooperation for Asia and the Pacific
FGD	Focus Group Discussion
FMOs	Flood Meteorological Offices
GISCs	Global Information System Centres
GLOSS	Global Sea Level Observing System
GSM	Global System for Mobile
HFL	Highest Flood Level
IAT	International Atomic Time
ICAR	Indian Council of Agricultural Research
IDI	In-depth Interview
IISc	Indian Institute of Science
IIT	Indian Institute of Technology
IITM	Indian Institute of Tropical Meteorology
IMD	India Meteorological Department
INCOIS	Indian National Centre for Ocean Information Services
IR	Infrared
ITU	International Telecommunication Union
IVRS	Interactive Voice Response System
JMA	Japan Meteorological Agency
KVK	Krishi Vigyan Kendras
MCTs	Multi-Purpose Community Telecentres

MHA	Ministry of Home Affairs
MoES	Ministry of Earth Sciences
MSSRF	MS Swaminathan Research Foundation
Mwp	Megawatt Peak
NCMSL	National Collateral Management Services Limited
NCs	National Centres
NDM	National Disaster Management
NIO	National Institute of Oceanography
NIOT	National Institute of Ocean Technology
NMHSs	National Meteorological and Hydrological Services
NMSs	National Meteorological Services
NVA	National Virtual Academy
NWP	Numerical Weather Prediction
PFZ	Potential Fishing Zone
PMSS	Probable Maximum Storm Surge
PTWC	Pacific Tsunami Warning Centre
PWSP	Public Weather Services Programme
RMS	Reuter Mobile Services
RSMC	Regional Specialized Meteorological Centre
RTSMN	Real-Time Seismic Monitoring Network
RTWPs	Regional Tsunami Watch Providers
SAUs	State Agriculture Universities
SMS	Short Message Service
SOI	Survey of India
SOP	Standard Operational Procedure
UNISDR	United Nations International Strategy for Disaster Reduction
USGS	United States Geological Survey
VKCs	Village Knowledge Centres
VP	Vulnerability Parameter
VRCs	Village Resource Centres
WIHG	Wadia Institute of Himalayan Geology
WMO	World Meteorological Organization
WRMSs	Weather Risk Management Services

Executive Summary

- In most countries, weather and climate are forecast by national meteorological services (NMSs).
- Lack of awareness of the economic value of NMSs in many countries has led to reduced public resources for these services. This has affected NMSs in two ways (i) Loss of accuracy in forecasting – Russia found a loss of accuracy and capability in its NMSs due to reduced expenditure on infrastructure and human resources and (ii) increased vulnerability – Mozambique found that in 2000, floods cost the country half of its GDP due to lack of weather/climate information that would have enabled effort to prepare for those floods.
- Subsequently in 2008 due to persistent requests by member countries, the World Bank reviewed the status of weather and climate services in Europe and Central Asia (ECA); it outlined the methodologies to assess the economic benefits of NMSs and provide cost-benefit analyses of investments in modernising NMSs.
- The review found that in addition to routine weather forecasts used by households:
  - NMSs provide weather forecasts to support around 30 sectors; of these, key sectors served in order of priority are agriculture, fisheries, disaster management, off-shore oil and gas exploration and insurance.
  - Per country financing on NMSs is 0.01 to 0.03 percent of GDP, and economic benefits tend to lie in the range of 0.3 to 1.2 percent of GDP.
- India's GDP at market prices (2009-10), at current prices, was ₹ 62,31,171 crore; per global average norms, the Ministry of Earth Sciences (MoES) budget for weather and climate forecasts should be around ₹ 1,200 crore (range is ₹ 643 crore to ₹ 1,689 crore); economic benefits due to weather and climate forecasts would be around ₹ 50,000 crore (range is ₹ 18,700 crore to ₹ 75,000 crore)
- In the Indian context, modernising NMSs, apart from improving accuracy in forecasting and decreasing vulnerability, serves the "inclusiveness" goal. The agriculture and allied sectors (fisheries) absorbs 71 percent of the rural labour force in India. Thus the Planning Commission has set the agriculture sector growth target at 4 percent to achieve a 9 percent GDP growth rate without un-due inflation and for the "inclusiveness" element in growth.
- The mid-term plan review by the Planning Commission (2010) stresses the immediate need for supply-side responses through weather forecasts and agriculture advisory services tailored to such forecasts.
- This study aims to estimate the *economic and social benefits of the services* provided by the MoES as well as realised benefits by beneficiaries, their perception on the reliability and utility of such services, etc. However, the MoES provides numerous services and the number of beneficiaries of these services are colossal. This study focuses on some specific services provided by the MoES and the economic and social impact of these services on a selected category of stakeholders. The services chosen for this study are agro meteorological advisory service, fishery services, tsunami warning services, severe weather warning services and public weather forecast services. Among the stakeholders, the study will focus on farmers, fishermen and the general public.

- The field study was carried out in 12 states and 1 union territory. For agromet services, two different sets of districts were selected, i.e., districts with Agro Met Field Units (AMFU) and districts without AMFU. In all, 20 districts across 10 states were chosen. For fishermen services, 4 districts across 4 states were chosen. For cyclone services, a list of cyclone-affected villages was procured from the cyclone relief department and five villages were chosen from two districts spread across two states.
- The economic benefits of meteorological services were based mainly based on

- Market price approach where market prices were used to measure the benefits of specialised meteorological services when treated as "private" goods – willingness by farmers to pay for specialised Reuters Mobile Services was used as a guide line; and
- Normative or prescriptive decision-marking model where meteorological information is regarded as a factor in the decision-making process by farmers to reduce uncertainty and thus assigned an implicit value by stakeholders.

- Awareness on the utility of ocean state information by fishermen as well as its use is quite high; more than 90 percent of fishermen were aware of these services in the southern coastal regions and around 64 percent in the eastern region.
- The catalytic role played by the MS Swaminathan Research Foundation (MSSRF), Village Resource Centres (VRC) and Village Knowledge Centres (VKC) in raising awareness and the "enabling" role of localised NGOs in facilitating knowledge transfer is evident from the Focus Study Group discussions and surveys.
- Identifications of Potential Fishing Zones (PFZs) as well as ocean state forecast by INCOIS are found to be both timely, accurate and of significant value to the fishing community.
- Identification of potential fishing zones increases productivity, significantly improves catch size and reduces fuel consumption, while the ocean state information is quite useful in timing departure and sequencing on shore activities and avoiding extreme weather-related emergency situations.
- The different parameters used by fishermen from daily weather and ocean state forecasts include: wind speed, wind direction, rainfall status, height and direction of waves, maximum and minimum temperature.
- Three scenarios have been considered to project the envisaged share of domestic product from fishing as well as economic benefits resulting from identification of PFZs
  - Scenario 1: Only mechanised crafts adopt PFZ
  - Scenario 2: Both mechanised crafts as well as motorised crafts adopt PFZ
  - Scenario 3: All mechanised crafts, motorised crafts and traditional crafts adopt PFZ

  In Scenario 1 the domestic product can go up from the present level of 0.81 percent of national GDP to 1.47 to 1.65 percent; in Scenario 2, it can go to 1.58 to 2 percent of national GDP and in Scenario 3 to around 2.04 percent of the national GDP.
- Net economic benefits have been computed as the premium (10%) earned on foreign exchange earned from exports of 21 percent of additional catch due to the identification of PFZ. The additional consumption benefits of fishermen, a part (33%) of which can be considered as the economic benefit in terms of *numeraire*, has also been included.
- Total annual net economic benefits due to the scientific identification of PFZs based on satellite information is estimated to lie in the range of ₹ 34,000 to ₹ 50,000 crore.
- INCOIS services to state governments such as Gujarat have been acknowledged as quite significant; however, certain states such as Andhra Pradesh are not keen to adopt INCOIS inputs. INCOIS needs to proactively sensitise and demonstrate the usefulness of its models to state governments.
- The key take-aways from the proactive role of INCOIS with the catalytic role of the partnering agency MS Swaminathan Research Foundation could be major milestones in the road map for progress in this sector. The win-win partnership enables the following: enables the roles of localised NGOs, adoption of "Fisher Friends Programme" through custom-built mobile handsets, identification of 'species-specific' PFZs leveraging technology options such as digital display board (IVRs) with NGO intermediation, etc.
- The proportion of farmers receiving weather information in both AMFU and non-AMFU districts is 24 percent.
- Roughly two-thirds of farmers receiving weather information in districts with AMFU reported using weather information, and roughly 23 percent of farmers profited by its use.

- Roughly 50 percent of farmers receiving weather information in districts without AMFU reported using weather information and roughly 17 percent of farmers reported benefitting by its use.
- Incremental benefits due to setting up of AMFUs seem to be in inducing more farmers to benefit from the use of weather information.
- Farm operations where farmers use weather information include: cropping patterns, sowing and harvesting, spraying of patricides, scheduling of irrigations and application of fertilisers
- Farmers receive weather information mainly through Krishi Darshan (TV) and newspapers. A small proportion of farmers in AMFU districts go through bulletins.
- Farmers' awareness on bulletins of Agro Advisory Services, on setting up Common Service Centres, etc. is quite low.
- Roughly 25 percent of the sample of farmers are willing to pay more for the detailed weather information and a significant proportion preferred the mobile phone route.
- Farmers subscribing to Reuters Mobile Services in five states were interviewed about the source of their information; 93 percent received and used the weather information over mobile phones; these were supplemented with weather information received from the TV, newspaper and other channels.
- The economic profit derived by farmers through the use of information provided by the IMD was calculated with the help of the survey. In the sample study roughly 24 percent of farmers were receiving weather information. Alternative scenarios of 50 percent farmers receiving weather information as well as that of 100 percent farmers receiving weather information were also considered.
- The economic benefit from the use of weather information was obtained as the product of the percentage of farmers receiving information, scenario-wise, times the percentage of farmers benefitting from the information times average profit, crop-wise, attributable to weather information times the total national production of crops. Conversion factors, crop-wise, were used to convert farmers' financial profits to economic profits.
- The economic profit estimates vary between ₹ 50,000 crore (where 24 percent farmers receive weather information) to ₹ 211,000 crore (where all farmers receive weather information). Since economic returns are quite sensitive to the proportion of farmers receiving information, there needs to be a specific budget for this item in IMD activities.
- The path forward for IMD would be to leverage its existing new relationship contracts with IFFCO Kisan Sanchar, e-Chaupal, Reuters Mobile Services, Hariyali, etc. to increase awareness among farmers on the utility of weather information services.
- IMD could also visualise a Farmers' Friends Programme on a pilot scale along the lines of the MS Swaminathan Research Foundation's Fishermen Friends Programme to institutionalise the NGO intermediation process in dissemination of weather information.
- The field survey brings out current community preparedness before the occurrence of a cyclone as well as coping strategies adopted during and after occurrence. These learnings can be factored into IMD's cyclone disaster prevention and mitigation programme.
- The net economic benefits of accurate detection of cyclones and adequate preventive measures can be significant as the case study on Nargis (May 3, 2008) in the context of Myanmar illustrates.
- Public weather services provided to households by IMD on heat/temperature, rainfall and cold weather are found to be relevant and useful by at least two-thirds of the households surveyed. Roughly 6 to 10 percent of households do not perceive any value or utility in such public weather information.
- Households' source of information is either TV/radio or newspapers; recently households have been tapping Internet sites to obtain information on the weather.
- Households perceive the utility of weather information in tackling health-related issues, finalising travel plans and in effecting the reduction of accidents.

CHAPTER I
Background and Scope of the Study

1.1 National Meteorological Services: World Bank Review in Europe and Central Asia

In most countries, weather and climate are forecast by National Meteorological Services (NMSs). In addition to routine weather forecasts used by households, NMSs often provide weather forecasts tailored to support agriculture, municipal services, disaster management, water resource planning and management, transport, environmental protection, public health, and other sectors (see Table 1.1 below for a list of key economic applications of weather and climate forecasts as drawn up by the World Maritime Organisation (WMO) based on a survey). In 2008, the World Bank reviewed the status of weather and climate services in Europe and Central Asia (ECA)[1]. This is a valuable study for outlining the methodologies to assess the economic benefits of NMSs and for providing cost-benefit analyses of investments in modernising NMSs in ECA.

Table 1.1: Economic Applications Served by National Meteorological Services

Average Rank Globally	As Ranked by the Services	Average Rank Globally	As Ranked by the Services
1	Aviation	16	Port and Harbour Management
2	Agriculture	17	Industry
3	Disaster Management	18	Urban Planning
4	Water Res. Planning and Management	19	Communications
5	Environmental Protection	20	Sport
6	Mass Media	21	Health and Medical Services
7	Construction	22	Leisure
8	Energy Generation and Supply	23	Offshore Operations
9	Marine Transportation	24	Legal Services
10	Tourism	25	Animal Husbandry
11	Fishery	26	Commerce
12	Land Transportation	27	Manufacturing
13	Food Production	28	Private Meteorological Service Sector
14	Forestry	29	Banking and Financial
15	Insurance	30	Retail Trade

Source: WMO (2001), "Responses to the Questionnaire on the Role and Operation of NMSs", Preliminary Analysis.

1.1.1 Key Sectors Likely to Benefit (as identified by the World Bank)

Worldwide, economic sectors are using improved weather forecasts to optimise their operations. According to the World Bank, of 30-odd sectors the key sectors likely to benefit most are:

Agriculture and Allied Sectors (Agriculture and Fishery): The agriculture sector could be a major beneficiary for the following reasons:

[1] Countries reviewed include: Kazakhstan, Kyrgyz Republic, Tajikistan, Turkmenistan, Uzbekistan (Central Asia); Armenia, Azerbaijan, Georgia (Caucasus); Belarus, Moldova, Ukraine (European CIS); Russian Federation; Albania, Bosnia and Herzegovina, Bulgaria, Croatia, Macedonia, Montenegro, and Serbia (South Eastern Europe).

- Accurate forecasts would enable timely sowing, ploughing, irrigation, and harvesting of crops. Increased accuracy would assist in the timing of applying fertilisers, in pest and disease control, and in avoiding over-applications that are washed or blown away.
- Forecasting could guide the cost-effective use of special preventive measures to mitigate the damage from frost, hail, drought, and erosion caused by wind and precipitation.
- Forecasting could be applied to optimise storage and transport of agricultural produce, reducing post-harvest losses.
- Forecasting could enhance pasture and animal production and fish catches—rainfall affects the availability of forage, and animal health depends on management that takes temperature and wind into consideration.

Disaster Mitigation is identified as the second major application. According to the United Nations International Strategy for Disaster Reduction (UNISDR), up to 35 percent of flood damage can be mitigated if flood warnings are made in advance; in the United States, as little as one hour of lead time can result in a 10 percent reduction in flood damage (UNISDR, 2004). Forecasting of severe weather enables emergency management teams to be put in place, mitigation measures to be prepared, and evacuation to be undertaken

Forecasts of precipitation can be used to help forecast the level of rivers by assessing the runoff that will result from precipitation. This method is becoming useful in basins where dangerous flows form rapidly and there are few gauges in place.

The study identifies other key sectors that would benefit, such as:

- *Aviation:* Aviation is an important client of hydrometeorological (hydromet) services, because safe aviation depends on weather forecasting.
- *Oil and gas extraction*. Better forecasting of temperatures would be useful to protect infrastructure for oil and gas extraction.
- *Insurance,* an emerging client of NMHSs, is a large, capable stakeholder interested in reducing weather-related damage that is insured.
- *Road, rail, and marine transport* make use of forecasts and information about current conditions, such as slippery surfaces, obscured visibility, and high winds.
- *Forestry* benefits from short-term weather forecasts of wind speed, temperature, precipitation and humidity that enable accurate forecasts of forest fires and smoke transport.
- The *health sector* is also making increasing use of weather alerts and advisories.

1.1.2 National Budgets for NMSs: World Bank Survey

The global sum of NMS budgets, an order-of-magnitude estimate, is US$4 billion for weather/ climate services. Per country, financing is usually on the order of .01 to .03 percent of GDP.

Financing models fall broadly into two categories: a pure public-goods model with full financing from the national budget, and a model that incorporates some self-financing through paid contracts for specialised services.

1.1.3 Assessment of Benefits of NMHS Operations/Modernisation

The World Bank made country-specific economic assessments of the benefit of NMS modernisation programmes for countries in the ECA. Two approaches were used. In the first approach, sectoral user needs assessments showed that weather losses in ECA are in the range of 0.5 to 1.9 percent of GDP annually in the countries studied. In the second approach, benchmarking studies estimated vulnerability within ECA by leveraging global average data and assessing each studied country's position within global ranges, comparing the country's position in the relevant country grouping considering climate, and the exposure of the national economy. Results by this method estimated annual losses in the range of 0.3 to 1.2 percent of GDP. In any case, outcomes are comparable, the level of loss is high, and the benefits of mitigating it are considerable.

India's GDP at market prices (2009-10) at current prices was ₹ 62,31,171 crore; per global average norm, the Ministry of Earth Sciences (MoES)[2] budget should be ₹ 1,200 crore (₹ 643 crore to ₹ 1,869 crore) and economic benefits around ₹ 50,000 crore (₹ 18,700 crore to ₹ 75,000 crore)

1.1.4 Factors Affecting Economic Returns: Accuracy, Vulnerability and Inclusiveness

Lack of awareness of the value provided by NMSs had limited the availability of public resources for these services. This affected NMSs in two ways:

Loss of Accuracy in Forecasting

Russia found the loss of accuracy and capability in its NMS to provide relevant, timely and accurate weather and climate services in the two decades between 1990 through the early 2000s appalling and started strengthening its infrastructure and human resources at NMSs.

In the context of Russia, study results were generalised and integrated to yield estimates of the current level of aggregate economic benefits from hydromet services, and then of the incremental benefit that could accrue from a modernisation project. This approach was a development of that undertaken in the Russian study, considering not only direct but also indirect losses. The potential effect of modernisation was then expressed as an increment of the prevented losses from hazardous and unfavourable weather conditions that would come about from an improvement in the quality of forecasts and hazardous weather warnings, compared to expenditures for modernisation of NMS plus the cost of the indicated preventive measures. Such estimates of benefits far outweighed expenditures on modernisation.

Vulnerability: Another Important Factor

An estimate in Mozambique suggested a cost-benefit ratio of 1:70 for investment in a national meteorological service. The explanation for this particularly high ratio is that the agency (once in

[2] The Ministry of Earth Sciences (MoES) was formed in 2006 from a merger of the India Meteorological Department (IMD), the National Centre for Medium Range Weather Forecasting (NCMRWF), the Indian Institute of Tropical Meteorology (IITM), Pune, Earth Risk Evaluation Centre (EREC), and the Department of Ocean Development. The Mission of the MoES is to provide the nation with forecasts of the monsoons and other weather/climate parameters, and information about ocean state, earthquakes, tsunamis and other phenomena related to earth systems through well-integrated programs.

possession of a rather strong network) lost most of its capacity during the country's 20-year conflict. Therefore, the investment being valued would in effect make the difference between a forecast versus no forecast. Moreover, in 2000, floods in Mozambique cost the country approximately half of its GDP; weather/climate information to enable efforts to prepare for those floods would have been extremely valuable.

Inclusiveness: An Important Factor in the Indian Context

In the Indian context in a growth scenario led by the service sector, inclusiveness demands that the agricultural growth target be fixed at 4 percent or more so that the 71 percent of the rural labour force dependent on agriculture and allied sectors is not deprived. Even if the sector share in the domestic economy is negligible, the inclusiveness goal in the national policy document would necessitate that the NMS's services be declared a public good for the benefit of India's important stakeholders, namely, farmers and fishermen.

1.2 Growth Rate of Agriculture and Allied Sectors: Key Components of Inclusiveness

As an important aspect of "inclusive growth" in the Eleventh Five-Year Plan (2007–12) the Planning Commission set a target of 4 percent per annum growth in GDP from agriculture and allied sectors. This target became necessary not only to achieve the overall GDP growth target of 9 percent per annum without undue inflation, but also as an important element of 'inclusiveness' in the growth of the economy.

The global experience of growth and poverty reduction shows that GDP growth originating in agriculture is at least twice as effective in reducing poverty as GDP growth originating outside agriculture. The latest NSS Report on employment and unemployment in India (2007-08) indicates that 71 percent of the rural labour force is dependent on the agricultural and allied sectors which can be considered as an important indicator of inclusiveness (Table 1.2)

Table 1.2: Work Force Dependent on Agriculture and Allied Sectors

Particulars	Gender	Rural	Urban	Rural+Urban
Population ('000)	Male	414938	176094	591032
	Female	392405	158572	550977
	Total	807343	334666	1142009
Total Work Force ('000)	Male	203320	93153	296473
	Female	73380	17919	91298
	Total	276700	111072	387771
Agriculture and Allied Sectors ('000)	Male	135207	5402	140610
	Female	61272	2741	64013
	Total	196479	8144	204624
Work Force in Agriculture and Allied Sector as Percent of Total Workforce		71.0%	7.3%	52.8%

Source: NSS Report No 531: Employment and Unemployment Situation in India. July 2007-June 2008.

1.2.1 Weather Phenomena Affects Growth Rate Performance in Agriculture and Allied Sectors

Growth in agriculture in 2007-08 was 4.9 percent. The continued strong growth recovery after 2004-05, which reversed a prolonged deceleration since the mid-1990s, led us to believe that we were on a higher agricultural GDP growth trajectory However, agricultural growth fell to 1.6 percent in 2008-09, and a severe drought in 2009 (the worst in 37 years) produced virtually flat growth because of major losses in kharif output which also led to high food price inflation. This is the macro evidence on the influence of weather on the agricultural and allied sectors′ growth performance.

Economic activities in agriculture and allied sectors are highly influenced by weather phenomena. The onset and withdrawal of monsoons, drought and floods, heat and cold waves are some phenomena that have a tremendous bearing on the economy. Therefore, weather forecasts play a crucial role in the growth and development of the economy.

1.2.2 Weather Forecasts Vital for the Sector's Stakeholders—Farmers and Fishermen

Key stakeholders like farmers, fishermen and the general public require accurate weather forecasts for their living. Agri-business is heavily influenced by the weather. Crop yields, quality, protein content and other factors can be dramatically affected by the weather. Daily operational decisions such as analysing crop rotations and planting, timing field maintenance programmes, planning effective crop spraying or deciding when to harvest depend on having accurate and timely weather information. Fish reproduction is highly sensitive to temperature fluctuations and so warming can have either positive or negative effects on egg production, depending on whether the target fish species is close to the thermal optimum. Rapid or dramatic increases in temperatures above normal maximum temperatures can have significant negative effects on the overall viability of some fish populations.

1.2.3 Weather Hazards

Weather hazards draw immediate attention due to their severe impact on life and property including agriculture. Cyclones and tsunamis affect coastal areas and have a hazardous impact on the country. Floods are another crisis that causes the biggest loss of life every year throughout the globe. Public weather services play an effective role in saving lives and property as well as for everyday convenience by providing public warnings, forecasts and other meteorological information in a timely and reliable manner. Some weather hazards appear to be less severe but their effects are slow and deep-rooted, causing direct and indirect damage to crops.

1.2.4 Do Stakeholders Derive Economic Benefits from Weather Forecasts?

Stakeholders derive economic benefits if there are interconnected links with users. The feedback mechanism requires the realisation of benefits by forecasts that are timely, frequent and adequate; further, the weather forecast should be put into user-friendly advisories, and the user should be educated about the potential of weather services and their usefulness. Economic benefit accrues to stakeholders when timely available information is put to productive use. Some factors that impact the realisation of benefits are interconnected links with users to understand their needs, providing need-based timely forecasts, and understanding the frequency and adequacy of the forecast required.

1.2.5 Stakeholder (Farmers and Fishermen) Share in Value of Sectoral Output

The main crops and horticulture account for around two-third of the value of the output in the sector while livestock accounts for one-fourth of the value. The fishery sector accounts for around 4.5 percent of the value of the sector output. The subsector-wise growth rate patterns shown below reveal that fishermen have been able to overcome adverse weather conditions quite effectively unlike the farmers' community as shown in Table 1.3 below:

Table 1.3: Subsector-wise Growth Rates of Gross Value of Output in Agriculture and Allied sectors

(percent)

	Share in value of output	Average growth 2000-01 to 2004-05	Projected growth for Eleventh Plan 2007-12	Year-on-Year Growth					Average 2005-06 to 2009-10
				2005-06	2006-07	2007-08	2008-09	2009-10	
1. Crops	42.4	1.0	2.7	6.3	4.0	6.1	-2.5	-5.5	1.7
1.1 Cereals	18.6	-0.5	2.3	5.4	5.5	4.9	1.7	-8.8	1.8
1.2 Pulses	2.7	1.7		3.0	5.4	7.4	-1.9	1.1	3.0
1.3 Oilseeds	6.2	6.2	4.0	14.5	-11.1	17.2	-3.7	-4.6	2.5
1.4 Sugarcane	3.7	-3.0	3.0	11.7	17.9	-1.6	-21.3	-11.8	-1.1
1.5 Fibres	2.8	7.7		7.8	18.7	17.0	-10.3	0.2	6.7
1.6 Other Crops	8.4	2.5		1.0	1.4	1.1	1.3	0.1	1.0
2. Horticulture	19.8	2.0	5.0	5.0	3.9	3.8	3.9	4.0	4.1
2.1 Fruits & Vegetables	15.1	1.7	-	6.4	3.6	5.2	3.7	4.8	4.7
2.2 Condiments & Spices	2.1	5.9	-	6.6	1.6	6.7	5.9	0.0	4.2
2.3 Drugs and Narcotics	1.5	-3.0	-	-8.2	3.2	-8.4	0.5	2.4	-2.1
2.4 Floriculture, Kitchen Garden & Mushroom	1.1	4.8	-	4.9	13.6	-2.6	6.9	3.5	5.3
3. Livestock	23.8	3.3	6.0	3.9	4.2	4.5	4.9	3.1	4.1
4. Forestry & Logging	9.6	1.4	0.0	2.0	3.0	2.2	2.9	2.7	2.6
5. Fishery	4.5	3.7	6.0	6.1	2.0	5.9	5.9	4.2	4.8
Total	**100.0**	**1.7**	**4.0**	**5.1**	**3.8**	**4.9**	**1.3**	**-0.3**	**3.0**

1.2.6 Agriculture and Allied Sectors: Short-term Subsector-wise Growth Analysis

Details of growth revival and variability in the short term can be discerned from Table 1.3 which gives subsector-wise details of output growth since 2005-06, comparing this to both the previous five-year period and Eleventh Plan projections. As far as sub-sector growth rates are concerned, the big picture is that average growth during 2005-10, though lower than Eleventh Plan targets for every sub-sector, was significantly higher for most sub-sectors than their average achievement for 2000-05. Since monsoon rainfall in 2009-10 was much more unfavourable than in 2004-05, this suggests that the near-doubling of overall output growth between these two periods cannot be attributed to weather alone. Thus, we can discern a longer-term trend for the agricultural sector growth rates *vis-à-vis* weather conditions.

1.2.7 Long-term trends in Agricultural Growth *vis-à-vis* Weather Conditions

The year-to-year variations in annual growth rates of agricultural output and agricultural GDP as measured by their standard deviation over five-year periods have now dropped to an all-time low although the absolute level remains high. This reflects not only better public-sector response to the 2009-10 drought but also probably a general improvement in the ability to adapt to adverse climate trends.

1.2.8 Recent Agricultural Policy Developments

Recent agricultural policy developments in India as per the OECD report "Agricultural Outlook 2010-2019 (OECD, 2010)" include increased volume of credit to a greater number of farmers and relief measures for indebted farmers facing crop failure. The budgeted investment for irrigation, product diversification and improved commodity marketing has been increased or promoted along with the development of income insurance schemes available to farmers. Several research and development programmes were launched in 2006 to enhance agricultural productivity. The economic environment for private initiatives was improved through measures taken for better functioning of commodity markets to reduce excessive regulation of the centre and state and to liberalise the trade of agricultural products. There has also been an effort towards redirecting resources from input subsidies to infrastructure development to help the sector grow faster.

OECD computed growth rates in agricultural production for OECD and emerging economies in the form of the net agricultural production index. The compounded annual rate of growth in agricultural production (2000-09) as well as the projected rate for the period 2010-19 is shown in Table 1.4.

Table 1.4: Compounded Annual Growth Rate of Net Agricultural Production Calculated for Selected Countries

(percent)

Country	CAGR 2000-09	CAGR 2010-19
USA	2.00	1.10
E-27	0.40	0.50
Canada	3.10	0.90
Australia	-0.70	1.30
China	2.50	1.90
India	2.70	1.50
Brazil	5.00	3.10
Russia	2.30	2.20
Ukraine	3.40	2.70

Source: OECD and FAO Secretariats.

Comparison of the two series show that, in future, agricultural production as projected by OECD for India is expected to decrease by 1.2 percentage points. Between 2000 and 2009, the Indian rate of growth of net agricultural production exceeded growth rates of net agricultural production in Russia and China; post-2010, as per OECD projections, Indian growth rates would lag behind the projected growth rates for China and Russia The international comparative analysis of policy developments also point out the need to tone up our supply-side response.

1.2.9 Mid-Term Appraisal of the Eleventh Five-year Plan (2007–12): Supply-side Response through Weather Forecasts and Agro-Advisory Services suited to such Forecasts are required

The Mid-Term Appraisal (Agriculture and Allied Sectors) has revealed certain inadequacies in the strategy and has concluded that much more needs to be done on the supply side. Not only are current rates of overall GDP growth increasing agricultural demand and putting pressure on food prices, but this is occurring in a decade which has been the hottest and also one of the driest since meteorological data have become available. Supply-side responses through weather forecasts and agri-advisory services tailored to such forecasts may be the requirement of the day. As per the OECD Report 2010, it turns out that the recent agricultural policy developments do not factor in supply-side responses on weather-related aspects for accelerating growth.

1.2.10 NMSs in India: MoES

The Ministry of Earth Sciences (MoES) was established by the Government of India in the year 2006 by bringing the meteorological agencies and ocean development department under one umbrella, given the importance of coupling ocean-atmosphere processes to understand the variability of weather, climate and hazards.

The mission of the MoES is to provide the nation with forecasting on the monsoons and other weather/climate parameters, ocean state, earthquakes, tsunamis and other phenomena related to earth systems through well-integrated programmes. These services have significant economic and social benefits that are otherwise difficult to quantify. The actual and potential benefits to the key stakeholders like individuals, firms, industry sectors and national bodies from state-of-the-art meteorological and related services are substantial.

Thus, a wide range of activities under such services are covered, contributing to various societal benefits in the areas of weather (general), weather advisories specific to agriculture, aviation, shipping, sports, etc., monsoon, disasters (cyclone, earthquake, tsunami, rising sea-levels), living and non-living resources (fishery advisory, poly-metallic nodules, gas hydrates, etc.), coastal and marine ecosystems and climate change. The programmes of the ministry have been recast broadly into various categories, *viz.*:

- (i) Atmospheric Science and Services
- (ii) Ocean Science and Services
- (iii) Cryosphere/Polar Science
- (iv) Ocean Resources
- (v) Ocean Technology
- (vi) Coastal Marine Ecology
- (vii) Climate Change Science
- (viii) Disaster Support
- (ix) Vessel Management
- (x) R&D in Earth Sciences
- (xi) Outreach

1.3 Scope of the Present Study

Keeping the above background in mind, the objectives of the NCAER study have been drafted as under:

The major objective of the study is to understand the perspectives of the main stakeholders on the weather and marine services being provided by the India Meteorological Department (IMD) and the Indian National Centre for Ocean Information Services (INCOIS).

That is, the study would aim to understand users' perceptions on the reliability, utility and realised benefits of services provided by the MoES and, if feasible, to assess the *economic benefits of such services*. However, the MoES provides numerous services and the number of beneficiaries is large. This study focuses on some specific services provided by the MoES that are restricted to the agriculture and fishery sectors and the economic impact of these services on a selected category of stakeholders, such as farmers and fishermen.

The services chosen for this study are agro-meteorological advisory service, fishery services, tsunami warning services, severe weather warning services and general weather forecast services.

The assessment of the services involves the following:

- Assessing the reliability, timeliness and adequacy of weather forecasts
- Accessibility of information and readiness of key stakeholders
- Valuation of the services from the perspective of the provider and users
- Institutionalisation and usage of these services and associated modifications adopted by the beneficiaries
- Understanding stakeholders' needs and their requirements of weather and marine services being provided
- Valuation of net benefits of services provided per stakeholders' perspectives
- Valuation of net benefits of meteorological services provided by comparing the users of such services with the control group
- Ability of stakeholders to use warnings on extreme weather conditions to mitigate losses.

In addition to understanding the perspectives of the main stakeholders, the study would attempt to identify:

- the key take-off from international experiences cited in the literature on the above aspects, and
- the key lessons from a preliminary study on organisational aspects of delivery of services and institutionalisation of processes.

1.4 Organisation of the Report

This report has nine chapters including the present one which provides an introduction to the study. The second chapter gives details on survey methodology and research design. The third chapter presents the awareness and use of weather information among fisherman while the fourth chapter elaborates on awareness and use of weather information among farmers. The fifth chapter deals with awareness and use of early cyclone warning information, and the sixth chapter deals with Tsunami Early Warning Systems. The seventh chapter deals with Weather Hazards (floods) and briefly looks at the IMD's role in mitigating the effects of weather hazards, Chapter 8 looks at IMD's role in providing public weather services and final chapter offers a summary and conclusion.

CHAPTER II
Survey Methodology and Research Design

This study aims to estimate the *economic and social benefits of the services* provided by the Ministry of Earth Sciences (MoES), as well as realised benefits by beneficiaries, and their perceptions of the reliability and utility of such services. The services chosen for this study are agro-meteorological advisory service, fishery services, tsunami warning services, severe weather warning services (cyclones) and general weather forecast services.

The present study uses a descriptive research design that involves 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.

2.1 Respondent Group and Study Area

The different types of respondent groups targeted in this study include:

- Farmers
- Fishermen
- General population in the age group of 18-45 years
- TV channels

The 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. The details of the districts covered in each state are presented in Annexure 1.

2.2 Sample Size and Coverage

Different types of users of weather services were interviewed in the present study. To collect information, different research techniques were adopted. Table 2.1 provides details of the coverage and sample size.

Table 2.1: Coverage and Sample size

	Research Technique	No. of States Covered	No. of Districts Covered	Sample Size (Targeted)	Sample Size (Achieved)
Quantitative					
With AMFU	Structured Interview	9	10	200	202
Without AMFU	Structured Interview	9	10	200	202
Fishermen	Structured Interview	4	4	400	400
Cyclone	Structured Interview	2	2	200	200
Mobile Users	Telephonic Interview	5		200	171
Qualitative					
For Cyclone study	FGD	2	2	10	10
TV Channel staff	IDI	7	-	12	7

Note: AMFU= Agro Met Field Unit

2.3 Sampling Design

Considering the requirements and design of the study, different sampling procedures were adopted to select the respondents. The sampling procedures adopted for different groups are discussed below.

2.3.1 For Agromet Services

In this segment, two different sets of districts were selected, i.e., districts with Agro Met Field Units (AMFU) and districts without Agro Met Field Units (AMFU). In total 20 districts were selected across 10 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.

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.

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.

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.

2.3.2 For Fishermen Services

Selection of Villages

A list of villages with the number of fishermen was procured from the district headquarters or the Fishery Department. All the identified villages were arranged in ascending order based on the number of fishermen in each village. Then five villages were selected using systematic random sampling.

Selection of Respondents

Each selected village was divided into four 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 fishermen available for interview.

2.3.3 For Cyclone Services

Selection of Villages

For selection of respondents in this category, a list of cyclone-affected villages was procured from the cyclone relief department. All the identified villages were arranged in ascending alphabetical order. Then five villages were selected using systematic random sampling.

Selection of Respondents

Each selected village was divided into four 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 at least one male/female in the age group 18-45 years.

2.3.4 Selection of TV channels

An attempt was made to select at least one popular regional TV channel from each state and interview the representatives.

2.3.5 Study Instruments

Seven study instruments were developed by the NCAER (four quantitative and three qualitative), which were translated into the regional languages. The instruments used for data collection are listed below:

1. Structured questionnaire for farmers
2. Structured questionnaire for fishermen
3. Structured questionnaire for cyclone-affected population
4. Structured questionnaire for mobile users (telephone interview)
5. Focus Group Discussion (FGD) guide for cyclone-affected population
6. In-depth Interview (IDI) guide for TV channels

2.4 Training and Field Operations

2.4.1 Training of Field Staff and Field Work

Training sessions were organised in various states. Researchers and senior field personnel of Sigma imparted the training at the state level. In each state, training was conducted for two days between the last week of September and the second week of October.

The training programme in each state was provided in the regional language. Interviewers were informed about the nature of interviews, the study tools to be used, and the specific skills required to elicit data. The training aimed at sensitising the interviewers and facilitating open discussion about the study. The training included an introductory session on the study objectives, target groups, importance of the study and implications of the study findings.

The methods adopted for training included discussion, role play, demonstration interviews, mock interviews and field practice. The objectives of the training programme were to ensure uniformity in data collection and accuracy and validation of the data collected.

The field work for this study was carried out during September and October 2010. In each state one team was deployed to carry out the field work. The FGD moderations were done by the team supervisors.

2.4.2 Quality Control Mechanism

To ensure quality data, the following quality control mechanisms were adopted:

- Proper and adequate training to all the field interviewers and supervisors irrespective of their prior experience
- Training as per the training schedule
- Assignments given to the field staff to assess their understanding levels during the training
- Scrutiny of completed interviews by the supervisor
- Spot-checks in the field by the supervisor/field executives (20% and 5%, respectively)
- Team meetings for de-briefing during field work
- Field visits by senior field professionals
- Accompanied interviews by supervisors / field executives
- Each interviewer was allowed to do no more than 25–30% of the total number of interviews

2.4.3 Ethical Issues

Adequate care was taken to conduct the research within international standards, particularly those stipulated by the WHO. All the respondents were provided information on the purpose of the study and informed consent was taken prior to their participation in the study. The details are presented below.

1) *Informed Consent:* All participants provided informed consent following standard and pre-agreed upon consent protocols.
2) *Systematic Inquiry:* The survey team conducted systematic, data-based enquiries.
3) *Integrity/Honesty:* The survey team displayed honesty and integrity in their own behaviour, and attempted to ensure the honesty and integrity of the entire survey process.
4) *Respect for People:* The survey team respected the security, dignity and self-worth of respondents, programme participants, clients, and other stakeholders.
5) *Responsibilities for General and Public Welfare:* The survey team articulated and took into account the diversity of general and public interests and values that may be related to the survey.

2.5 Data Processing and Analysis

All the completed questionnaires were scrutinised at the field level and sent to the data processing unit for entry. Data entry was done at Delhi using the Census and Survey Processing System (CS Pro) package. After data entry, the frequency for all variables was checked and the data was cleaned. Analysis of the quantitative data was carried out by in-house analysts using SPSS 15.0.

The Focus Group Discussions were audio-recorded, transcribed and translated into English. The transcripts of both FGDs and IDIs were entered into spreadsheets. A spreadsheet was prepared for content analysis, which is used for report writing. Verbatim quotes have been provided as evidence and to provide a direct feel for responses. These are presented in this report in italics.

2.6 Profile of Respondents

This section presents the profile of the respondents and their household characteristics.

2.6.1 Profile of Farmers

Age

The mean age of farmers in AMFU districts is 44 years, and 45 years in districts without AMFU. Two-fifth of the farmers in non-AMFU districts compared to 28% in AMFU districts are 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) are male (Table 2.2).

Table 2.2: Percent Distribution of Farmers by Age and Gender

	With AMFU	Without AMFU
Age (in years)		
< 19	0.0	0.5
20-29	14.3	9.4
30-39	23.7	18.8
40-49	27.8	40.1
50+	33.2	30.7
No response	1.0	0.5
Mean Age	44.4	45.2
Gender		
Male	93.6	96.5
Female	6.4	3.0
Total N	**202**	**202**

Level of Education

Table 2.3 provides the level of education among farmers. 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 have a B.A. or higher degrees.

Table 2.3: Distribution of Farmers by Level of Education

(percent)

Education level	With AMFU	Without AMFU
Illiterate	23.8	18.8
Below Primary	5.0	10.9
Primary	13.4	10.4
Middle	20.8	18.8
High School	20.3	19.3
Higher Secondary	11.4	11.9
Graduation and above	5.4	9.4
Total N	**202**	**202**

Category of Land holdings

Table 2.4 gives the category of land holdings among farmers. The majority of the farmers in both types of districts have homestead land. Two-third of the farmers in AMFU districts and three-fifth in non-AMFU districts reported that they owned cultivated land. The percentage of farmers in both districts who reported that they leased land is very low.

Table 2.4: Percentage of Farmers by Category of Land holding

Categories	With AMFU	Without AMFU
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 N	**202**	**202**

Note: The total exceeds 100 due to multiple responses.

Sources of Irrigation

The majority of the farmers reported that their main source of irrigation was tube wells—two-third (64%) in non-AMFU districts and three-fifth (57%) in AMFU districts. Farmers in both the districts also cited wells as another irrigation source (Table 2.5).

Table 2.5: Distribution of Farmers by Irrigation Sources

(percent)

Source of Irrigation	With AMFU	Without AMFU
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**

Housing Characteristics of Farmers

The findings on the housing characteristics of the household are presented in Table 2.6. The majority of the farmers own a house. Two-fifth of the farmers in AMFU districts while more than half the farmers in non-AMFU districts reported having 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 AMFU districts and 67% in non-AMFU districts) reported taps as the drinking water arrangement.

Table 2.6: Housing Characteristics of Farmer Households

(percent)

Categories	With AMFU	Without AMFU
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 N	**202**	**202**

2.6.2 Profile of Fishermen

Age

The mean age of fishermen covered in this study is 39 years. Across the states the mean age of fishermen varies— from 35 years in Kalyani district of West Bengal to 44 years in Puducherry. A gender-wise analysis shows that almost all the fishermen covered are male (Table 2.7).

Table 2.7: Distribution of Fishermen by Age

(percent)

Age	Kalyani (WB)	Guntur (AP)	Nagapattnam (TN)	Puducherry (PND)	All
< 19	2.0	0.0	0.0	0.0	0.5
20-24	14.1	0.0	7.0	3.0	6.0
25-29	14.1	24.0	14.0	5.9	14.5
30-34	6.1	18.0	16.0	15.8	14.0
35-39	18.2	15.0	13.0	13.9	15.0
40-44	23.2	13.0	7.0	13.9	14.3
45-49	22.2	20.0	12.0	7.9	15.5
50+	0.0	10.0	31.0	39.6	20.3
Mean	35.6	37.2	40.8	44.2	39.5
Total N	**99**	**100**	**100**	**101**	**400**

Level of Education

The educational level of the fishermen covered in this study suggests that more than one-third are illiterate and another one-tenth have an education below primary level. The percentage of illiterates varies from 14% in Nagapattanam district of Tamil Nadu to 62% in Guntur district of Andhra Pradesh. Only in Puducherry and Nagapattanam more than one-tenth of the fishermen have an educational level of high school and above (Table 2.8).

Table 2.8: Distribution of Fishermen by Level of Education

(percent)

Education	Kalyani (WB)	Guntur (AP)	Nagapattnam (TN)	Puducherry (PND)	All
Illiterate	45.5	62.0	14.0	24.8	36.5
Below primary	22.2	12.0	7.0	8.9	12.5
Primary	16.2	12.0	41.0	24.8	23.5
Middle	13.1	13.0	28.0	28.7	20.8
High school and above	3.0	1.0	10.0	12.8	6.7
Total N	**99**	**100**	**100**	**101**	**400**

Housing Characteristics

The data analysis suggests that almost all the fishermen covered in the study own the houses they live in. The combined value for all four areas suggests that about three-fifth (59%) of the fishermen have *pucca* houses. The percentage of fishermen having *pucca* houses varies from 26% in Kalyani district of West Bengal to 86% in Puducherry. In Kalyani district more than half the fishermen interviewed have *kuchcha* houses (Table 2.9).

Table 2.9: Housing Characteristics of Fishermen

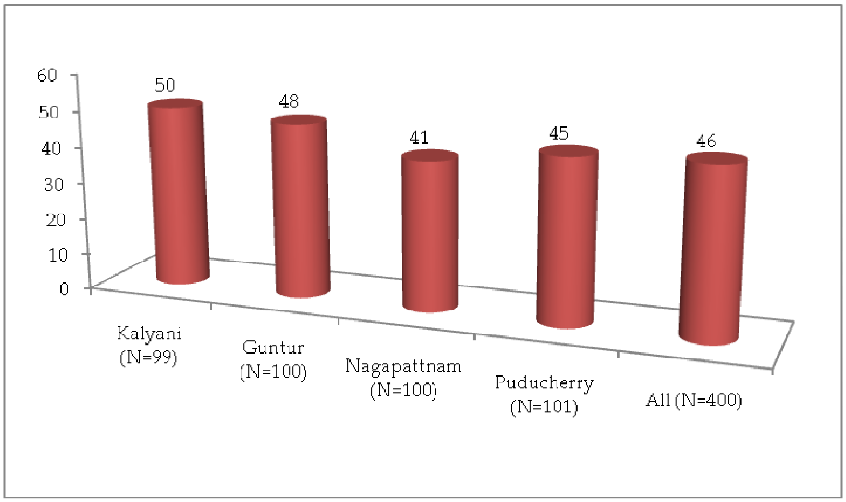
(percent)

Type of House	Kalyani (WB)	Guntur (AP)	Nagapattnam (TN)	Puducherry (PND)	All
Kuchcha	51.5	25.0	28.0	10.9	28.8
Pucca	26.3	64.0	60.0	86.1	59.3
Semi-pucca	22.2	11.0	12.0	3.0	11.9
Total N	**99**	**100**	**100**	**101**	**400**

Ownership of Boat

During the survey the fishermen were asked whether they owned a boat for their fishing operations. About half (46%) the fishermen own a boat and this is true for all districts together (Figure 2.1).

Figure 2.1: Percentage of Fishermen Who Own a Boat



2.6.3 Profile of Respondents for Cyclone Study

Age

The mean age of respondents covered in the cyclone study is 35 years. One-fourth of the respondents in the general population are 45 to 49 years. The percentage of respondents aged 40-49 years is higher in Bapatla than in Kalyani. A gender-wise analysis shows that more than two-third of the respondents covered in the survey are male and one-third are female (Table 2.10).

Table 2.10: Distribution of Respondents by Age and Gender

(percent)

Age (in years)	Bapatla	Kalyani	All
< 19	0.0	6.0	3.0
20-24	7.0	21.0	14.0
25-29	6.0	16.0	11.0
30-34	8.0	21.0	14.5
35-39	17.0	15.0	16.0
40-44	23.0	10.0	16.5
45-49	35.0	11.0	23.0
50+	4.0	0.0	2.0
Mean Age	39.2	30.9	35.1
Gender			
Male	85.0	55.0	70.0
Female	15.0	45.0	30.0
Total N	100	100	200

Level of Education

Table 2.11 provides the level of education of the respondents. Nearly half the respondents are illiterate with two-third in Bapatla and one-fourth in Kalyani. One-fifth of the respondents have completed middle school. This is higher in Kalyani (28%) than in Bapatla (8%).

Table 2.11: Distribution of Respondents by Level of Education

(percent)

Education level	Bapatla	Kalyani	All
Illiterate	67.0	26.0	46.5
Literate	5.0	8.0	6.5
Primary	6.0	18.0	12.0
Middle	8.0	28.0	18.0
High School	5.0	8.0	6.5
Higher Secondary	5.0	4.0	4.5
Graduation and above	4.0	8.0	6.0
Total N	**100**	**100**	**200**

Occupation

The occupation of the respondents is presented in Table 2.12. Nearly two-fifth of the respondents are cultivators while one-fourth work as labourers. One-fifth of the respondents are housewives. About one-fifth (16%) of the respondents are in fishing operations or have a petty trade.

Table 2.12: Occupation of Respondents

(percent)

Occupation	Bapatla	Kalyani	All
Cultivator	55.0	20.0	37.5
Labourer	26.0	22.0	24.0
Fishermen	14.0	2.0	8.0
Petty trade	4.0	11.0	7.5
Housewife	1.0	32.0	16.5
Student	0.0	4.0	2.0
Not working	0.0	9.0	4.5
Total N	**100**	**100**	**200**

2.7 Methodology

2.7.1 Economic Benefits of Meteorological Services

A number of approaches have been developed to estimate the economic benefits of meteorological services. These include:

- Market price approach. Market prices are used to measure the benefits of specialised meteorological services when treated as 'private goods';
- Normative or prescriptive decision-making models;
- Descriptive behavioural response studies (including user surveys and regression models);
- Contingent valuation models;
- Conjoint analysis;
- Economic Analysis Guidelines: ADB, World Bank and Planning Commission methodologies.

Each of these methods is examined below.

2.7.2 Market Price Approach

Market prices can be used as a measure of the marginal benefits to users of meteorological information, which have 'private good' characteristics. The advantage of market prices is that they explicitly reveal the value that users place on and are willing to pay for particular categories of meteorological information. For instance, if Reuters is able to commercialise meteorological information and sell it to interested farmers, then their sale price, net of expenses, can be an estimate of the value placed by farmers on the information. There are limitations to this approach. During the field surveys, both the farmers and fishermen insisted that in view of the 'public good' nature of such information, the government should absorb all expenses. Both communities were aware of the importance of such information to their livelihood.

2.7.3 Normative or Prescriptive Decision-Making Models

This approach views meteorological information as a factor in the decision-making process that can be used by decision makers to reduce uncertainty. Here it is assumed that the decision makers are members of the farming and fishing community. A surrogate approach often used (even in our surveys) is to compare farmers with a similar socio-economic background both from target areas (where information flow is facilitated) as well as from control areas.

2.7.4 Descriptive behavioural Response Studies

"Anecdotal" reports, case studies, and user surveys are examples of such an approach that gives a qualitative experience. The Focus Study Group method of compiling/ capturing qualitative information has been adopted for this study.

2.7.5 Contingent Valuation Models

The contingent valuation method is a non-market valuation method used by some analysts in relation to 'public good' meteorological information. We have not tried to elicit such information from our surveys as they can be subjective and misleading.

2.7.6 Conjoint Analysis

This is similar to contingent valuation in that it also uses a hypothetical context in a survey format involving the users of meteorological information. The survey questions in conjoint analysis are designed as choices between and/or ranking of preferences for alternatives with multiple attributes. This was not considered suitable as our major stakeholders, namely, farmers and fishermen are not aware of such outcomes/scenarios

2.7.7 Economic Analysis Guidelines: ADB, World Bank and Planning Commission Methodologies

Economic analysis of costs and benefits of providing NMSs services is significantly different from their financial analysis. Economic analysis attempts to measure the overall impact of the programme on improving the economic welfare of the citizens of the country. It assesses the project in the context of the national economy rather than the project entity. For instance, a programme′s positive and negative impacts are measured in terms of willingness to pay or in terms of benefits foregone or in terms of disaster funds earmarked to overcome the adverse impact.

Economic analysis differs from its financial analysis counterpart both in terms of identification and evaluation of inputs and outputs and in measurement of cost and benefits. The financial analysis of a programme estimates the profit accruing to the programme – the operating entity – or to the programme participant, whereas economic analysis measures the effect on the national economy. For a programme to be economically viable, it must be financially sustainable, as well as economically efficient. If a programme is not financially sustainable, economic benefits will not be realised. Financial analysis and economic analysis are therefore two sides of the same coin and complementary; thus, programme financial analysis should be undertaken in conjunction with programme economic analysis.

Looked at from another perspective, financial prices influence the decisions of programme participants; economic prices record the consequences of those decisions for the national economy. Financial prices help determine the level of demand for programme outputs and the level of supply of programme inputs. Prices or user charges, demand and the scale of investment need to be considered simultaneously.

For our study private sector gains, such as farmers and fishermen groups′ gains, need to be translated to the *numeraire* (yardstick) such as uncommitted income in the hands of the government so that NMSs′ budgeted expenditures can be compared with the financial gains of these groups at the social discount rate. Since inclusiveness is a national goal as spelt out in the mid-term appraisal of the Planning Document, we consider these farmers and fishermen groups as reference groups meaning that their gains/losses will be treated at par with the gains and losses of the uncommitted income in the hands of the government.

CHAPTER III
Awareness and Use of Weather Information Among Fishermen

With a coastline of over 8,000 km, an Exclusive Economic Zone (EEZ) of over 2 million sq. km., and with extensive freshwater resources, fishery play a vital role in the economy. At present, fishery and aquaculture contribute about 1.07 percent to the national GDP. The average annual value of output during the year 2008-09 was ₹ 49.900 crore.

India is the third largest fish producer in the world with nearly 6 million fishermen, of which 2.4 million are full-time, 1.45 million are part-time and the rest are occasional fishermen. Fishing is mainly conducted in traditional fishing crafts, motorised boats (most converted from traditional boats) and small-mechanised craft. There are about 2,20,000 traditional craft, 40,000 traditional motorised craft and 52,000 mechanised boats operating in Indian waters. There are two wide varieties of fish in India's EEZ – pelagic and demersal. Pelagic fish (sardine, mackerel, tuna, etc.) live principally in the upper layers of the ocean, near the surface, and demersal fish (cod, flat fish, cat fish, skates, rays, etc) live near the ocean bottom. The major share of resource is demersal (2.02 million tonnes) followed by pelagic (1.67 million tonnes).

Changes in weather patterns affect fishery in various ways with major implications for production. For example, great drought or severe flooding can reduce fish catches as fish may migrate to deeper water with increasing temperatures. Rising water temperatures may also reduce the upwelling of food that the fish in the upper layers depend on. In recent years with the increase in the number of fishing fleets, there is tremendous pressure on the traditionally known fishing grounds, which is leading to a fall in Catch per unit Effort (CPUE). Hence there is a need to direct some fishing effort to other suitable potential fishing areas, which can be explored by using remote sensing.

3.1 Fishery

Fishery account for over 4.5 percent share of value of output in the agricultural and allied sectors; however, the number of stakeholders dependent on the sector for livelihood is quite large. Currently, inland and marine fishery account for around 0.81 percent of national GDP as per the Central Statistical Organisation (CSO) (2008-09). For over a decade, the Department of Space, Department of Ocean Development (and now under the Ministry of Earth Sciences), and several institutions under the Ministry of Agriculture have jointly endeavoured with the state governments of the marine states and islands to provide Potential Fishing Zone (PFZ) advisories to the Indian fishing community. The Indian National Centre for Ocean Information Services (INCOIS) is an autonomous body formed under the MoES, Government of India that provides ocean information and advisory services to society, industry, the government and the scientific community. Some significant activities of INCOIS are to identify and disseminate information about PFZs, give early warning of tsunamis and provide detailed information on the status of sea waves and sea currents as forecast by the Indian Ocean Forecasting System.

3.1.1 Identification of Potential Fishing Zones (PFZ)

Identification of Potential Fishing Zones (PFZ) including the availability, type and quantity of fish has been one of the main pre-requisites for economical fishing activity. The traditional indicators used by fishing communities to identify potential fishing zones are as follows: the congregation of birds, colour and smell of sea water, bubbles breaking on the sea surface, and muddy or oily water on a calm sea. With scientific parameters such as sea surface temperature, chlorophyll, nutrients, dissolved oxygen, salinity, winds and currents, the feeding and breeding habits of fish can be forecast. Information on these parameters is derived from satellites and *in situ* platforms[3]. Ocean colour is a significant index that involves relationships with biological, chemical and physical processes. Chlorophyll pigment concentration is a convenient index of phytoplankton biomass which can be measured from space. Data from Coastal Zone Color Scanners (CZCS) provide the first view of chlorophyll concentration and models are applied to estimate the concentration. With the operational use of NOAA satellites, the temperature of the sea surface is measured. The relationship between ocean colour and the sea surface temperature is estimated through a clustering technique called ARNONE. From the composite image, the position of the PFZ is determined on the basis of latitude and longitude. With the help of hydrographic maps, the depth of their location is read. This information is disseminated to users mainly through web pages and digital display boards, as well as other means such as SMS, media, and telephone.

3.1.2 Ocean State Forecast System

The Ocean State Forecast System forecasts the likely status, such as 24-hour or 48-hour status, for sea conditions for a wide variety of physical variables. For instance, wave forecast aims to forecast the distributions of wave height contours at 00 hrs to 1200 hrs on a daily basis for users. The vital ocean parameters which have direct implications on navigation and safe operations are sea surface waves, remotely generated waves (swell waves), ocean surface winds, ocean currents, sea surface temperature, mixed layer depth, etc. The duration, accuracy and spatial resolution of the forecast depend on the users. While coastal fishermen want information two days in advance, the Navy requires it ten days in advance. Offshore industries are interested in the onset of the monsoon and extreme conditions.

3.1.3 The Validation

To test the accuracy and reliability of forecast products, they must be compared with the observations. *In situ* and satellite measurements are used for validation. While *in situ* measurements provide the most accurate data for validation, their spatial coverage is limited. On the other hand, satellite data provides wide spatial coverage. Validation is done mainly during extreme conditions and the monsoon seasons.

[3] For details, see www.incois.gov.in

3.1.4 The Users

Users include maritime boards, the Navy, coast guard, the shipping and energy sectors, oil industries, fishermen, and NGOs. To increase awareness among users, INCOIS conducts user interaction meetings at various places; user requirements and feedback are collected regularly to improve the products. INCOIS has started location-specific forecast activity to serve the fishing community in collaboration with personnel from the local community centre whose role is to translate the information into the local language and explain it to the users. The location-specific forecast is disseminated through village information centres, All India Radio, FM radio, digital display boards, NGO websites and TV channels in local languages. The information is updated daily.

3.2 New Services in 2010

3.2.1 High-Wave Alerts

INCOIS has started providing alerts for high-wave conditions during the monsoon and cyclone periods. They had provided these advisories for the past three cyclones, namely, Laila, Phet, and Jal and during the onset of the south-west monsoon. The services were well received by the user community such as fishermen, port and harbour, and maritime boards.

3.2.2 Tidal Forecast System

Information on predicted ocean tides (for five days) for a number of stations along the coastline of the Indian subcontinent is now routinely disseminated through the web (as time series plots / High-Low listings). The basic data used for the purpose is the tidal harmonic constants (amplitude and phase) from the National Institute of Oceanography (NIO), Goa.

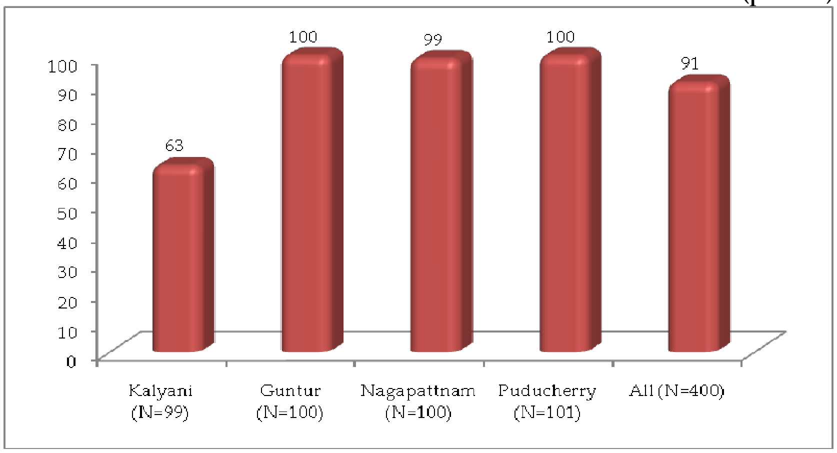
INCOIS has launched the Sea State Forecasting system for the islands of Andaman and Nicobar and the Lakshwadweep Islands.

3.3 Awareness and Sources of Weather Information

The survey attempted to assess the level of awareness of weather forecast services among fishermen. It found that more than 90 percent of the fishermen are aware of weather forecast services.

Figure 3.1: Fishermen Aware of Weather Forecast Service

(percent)

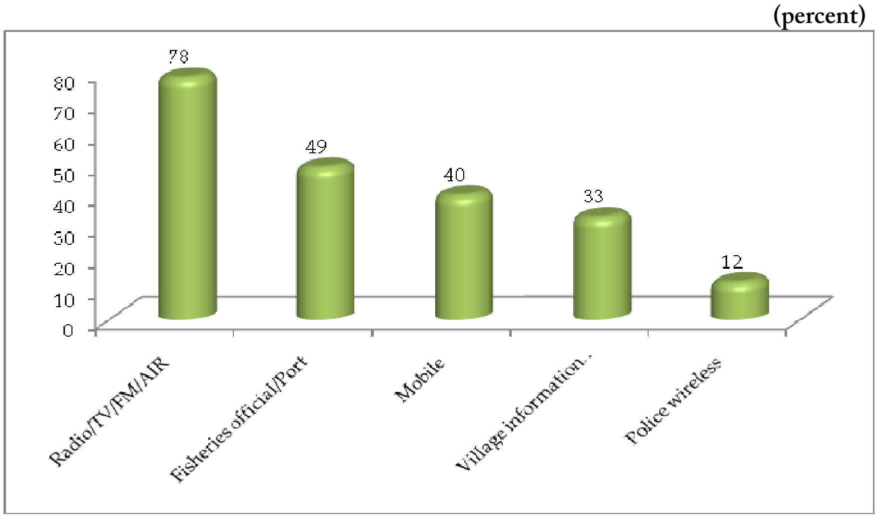


3.3.1 Sources of Weather Information

Those fishermen who follow daily weather information in their everyday fishing operations were asked about their sources of information. The five major sources of information reported by the fishermen are radio/TV/FM/AIR (78%), fishery officials/ port (49%), mobile phone (40%), village information system (33%), and police wireless system (12%).

Figure 3.2: Sources of Weather Information Reported by Fishermen

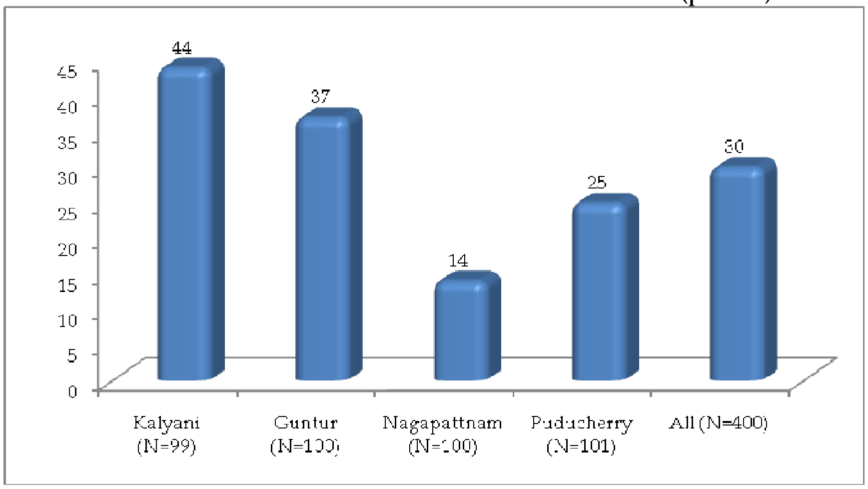
(percent)



3.3.2 Traditional Methods for Weather Forecast

Of the fishermen covered in this study, only 30 percent reported that they use traditional methods for weather forecast. Use of traditional methods for weather forecasting varies from 14 percent in Nagapattanam of Tamil Nadu to 44 percent in Kalyani district of West Bengal.

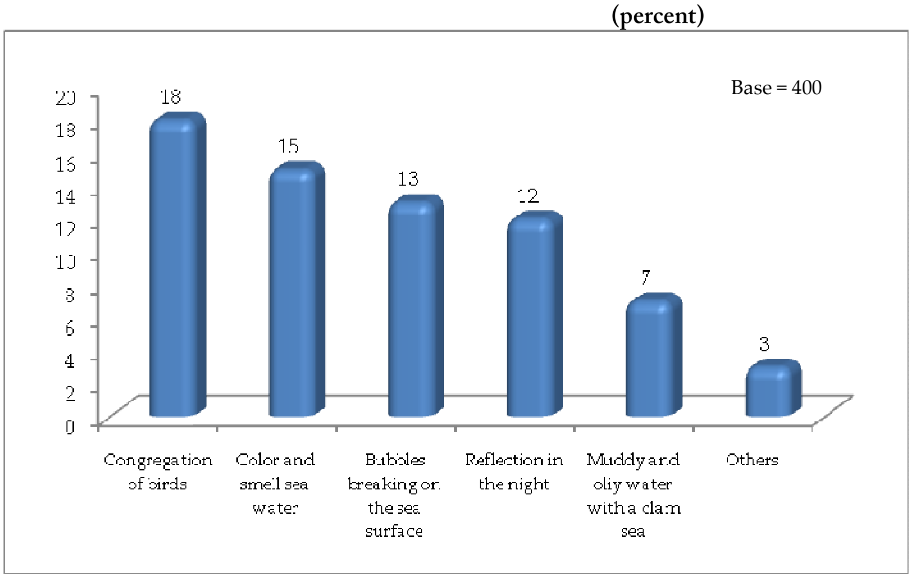
Figure 3.3: Fishermen using Traditional Methods for Weather Forecast (percent)



3.3.3 Type of Traditional Sources for Identification of PFZ

The survey also tried to find the types of traditional sources used to identify potential fishing zones (PFZ). Figure 3.4 presents the findings pertaining to this. About 18% of fishermen still use congregation of birds to identify PFZs. Similarly, 15% also uses colour and smell of sea water to identify the PFZs. Bubbles breaking on the sea surface and reflection in the night are also used by one-tenth of the fishermen.

Figure 3.4: Types of Traditional Sources Used to Identify Potential Fishing Zones (percent)



3.4 Use of Weather Information

3.4.1 Parameters used for Weather Forecast

Table 3.1 lists the parameters used by fishermen for daily weather forecasts in their everyday fishing operation. More than three-fourth of the fishermen use wind speed, while two-third use rainfall status and wind direction. In addition to these parameters, about half the fishermen also use the height and direction of waves and about one-third (31%) use maximum-minimum temperature for their fishing operations.

Table 3.1: Parameters Used by Fishermen for Daily Weather Forecast in Fishing Operations

(percent)

Parameter	Kalyani (WB)	Guntur (AP)	Nagapattnam (TN)	Puducherry (PND)	All
Wind speed	48.5	63	100	95	76.8
Rainfall	34.3	38	99	99	67.8
Wind direction	40.4	62	80	88.1	67.8
Wave height and direction	10.1	61	63	59.4	48.5
Maximum - Minimum temperature	11.1	24	55	33.7	31
Probability and strength of gust	40.4	37	3	2	20.5
Sea surface temperature	1	59	5	2	16.8
Potential Fishing Zone	22.2	0	35	3	15
Visibility and sea state	1	24	5	6.9	9.3
Sea surface current	1	17	0	9.9	7
Mixed layer depth	18.2	1	1	1	5.3
Conductivity and water current	4	1	0	0	1.3
Barometric pressure	1	0	0	0	0.3
Total N	**99**	**100**	**100**	**101**	**400**

Note: Total exceeds 100 due to multiple responses.

3.4.2 Importance of Weather Information

The fishermen were asked about the importance of weather information in fishing operations. More than fourth-fifth (89%) of the fishermen feel that the information is more useful in co-ordination during departure and about half (47%) feel that weather information is important in dealing with emergency situations during fishing. Other important uses of weather information stated by the fishermen include using suitable tools for fishing, stock of food/diesel, preparating for fishing/ getting deliveries of ice and identifying catchment zones (Table 3.2).

Table 3.2: Importance of Weather Information in Fishing Operations

(percent)

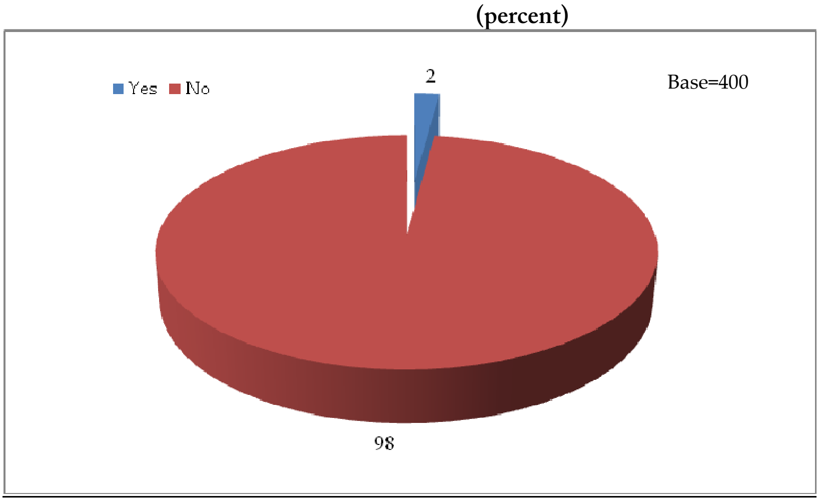
Category	Kalyani (WB)	Guntur (AP)	Nagapattnam (TN)	Puducherry (PND)	All
Co-ordinating departure	62.6	98	98	95	88.5
During fishing emergencies	14.1	26	77	71.3	47.3
Using suitable tools for fishing	60.6	91	0	1	38
Stocking food, diesel, etc	4	100	32	5.9	35.5
Getting deliveries of ice	22.2	99	4	6.9	33
Identifying catchment zones	64.6	15	13	29.7	30.5
Call factories after fishing	2	88	0	0	22.5
Finding market rates	37.4	16	16	15.8	21.3
Selling fish	26.3	46	0	0	18
Collecting fish	44.4	14	0	0	14.5
Total N	**99**	**100**	**100**	**101**	**400**

3.4.3 Willingness to Pay for Weather Information

The fishermen were asked whether they were willing to pay to receive weather information. Figure 3.5 shows that almost all the fishermen are not willing to pay for this information. Of them, about one-fifth stated that they want the services free of cost, whereas others gave no reason. Of the eight fishermen who are willing to pay for weather information, five belong to Kalyani district of West Bengal and three belong to Nagapattanam district of Tamil Nadu.

The results clearly suggest that though the fishermen are aware of the importance of weather information, they are not willing to pay for such services, but if they get these services free then they will use them.

Figure 3.5: Willingness to Pay for Weather Information (percent)

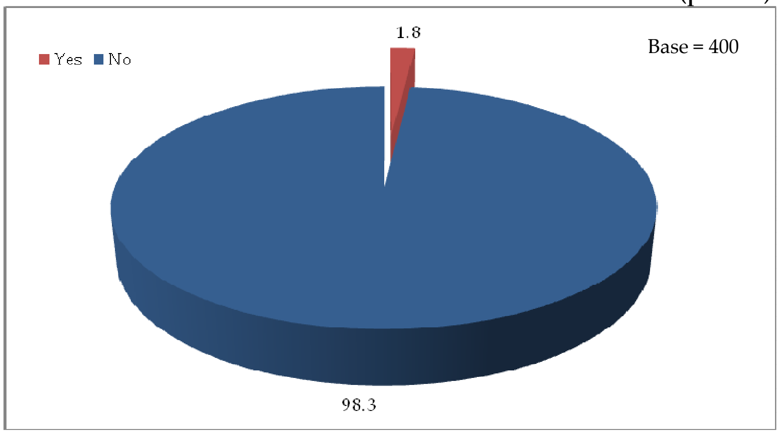


3.4.4 Registered Users of INCOIS

To find the extent of mobile phone use to get weather information, the fishermen were asked whether they are registered users of INCOIS (Indian National Centre for Ocean Information Services). The results show that a negligible percentage of fishermen are registered users of INCOIS. All seven fishermen who are registered users of INCOIS belong to Nagapattanam district of Tamil Nadu.

Figure 3.6: Fishermen who are Registered Users of INCOIS

(percent)



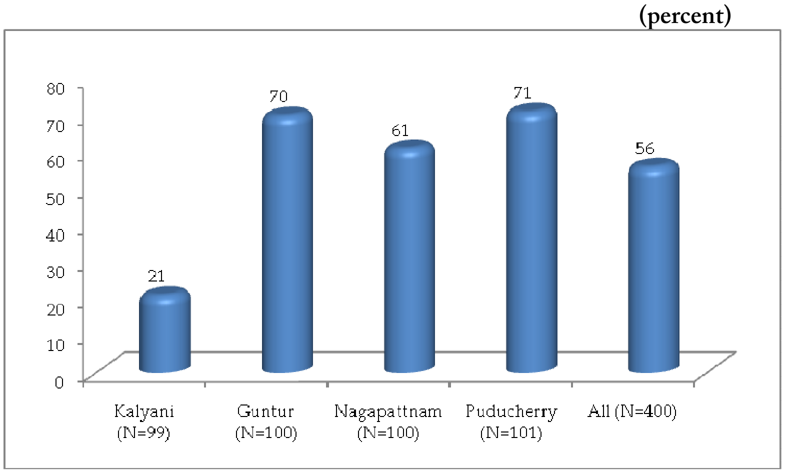
3.5 Awareness among Mobile Users about Weather Information

3.5.1 Use of Mobile Phones in Fishing

Figure 3.7 presents the findings on the use of mobile phones among fishermen in fishing and other operations. More than half the fishermen (56%) use mobile phones in fishing work and other operations. The use of mobile phones among fishermen varies from 21% in Kalyani district of West Bengal to 71% in Puducherry.

Figure 3.7: Fishermen Who Use Mobile Phones in Fishing and Other Operations

(percent)

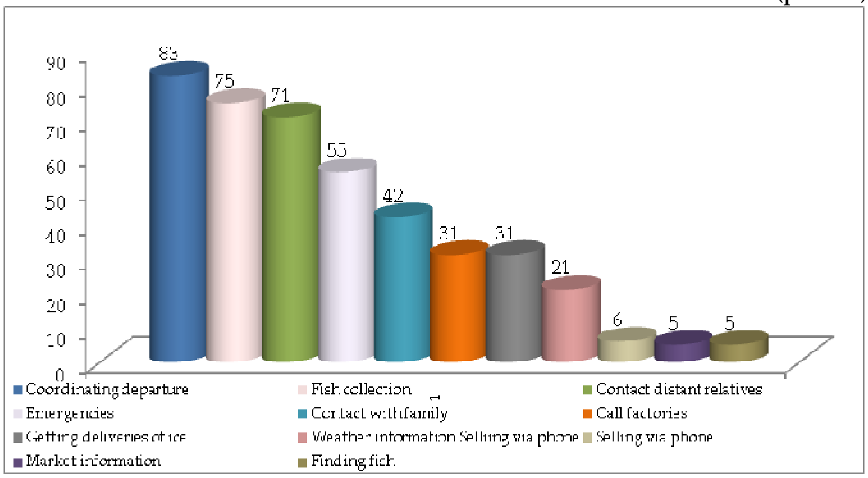


3.5.2 Advantages of Mobile Use

The fishermen who use mobile phones in fishing and other operations were further asked about the types of services availed of through the phones. The fishermen use their phones mainly to co-ordinate their departure (83%), check the status of fish collection (75%) and contact their relatives (71%). More than half the fishermen also use mobile phones to communicate during an emergency.

Figure 3.8: Services Availed through Mobile Phones among Fishermen

(percent)



3.5.3 Interactive Voice Response System (IVRS)

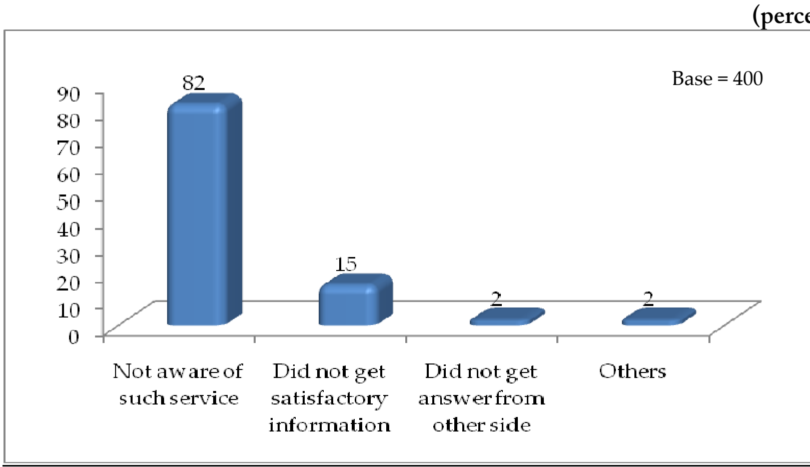
All the fishermen interviewed were asked about the use of the Interactive Voice Response System (IVRS), but only 3% of them use these services.

3.5.4 Constraints in using IVRS

Those who do not use the services of IVRS were asked for the reasons. Of the fishermen covered in the study, more than four-fifth (82%) are not aware of IVRS and 15% reported that the information received through IVRS is not satisfactory.

Figure 3.9: Reasons for Not Using Interactive Voice Response System (IVRS)

(percent)

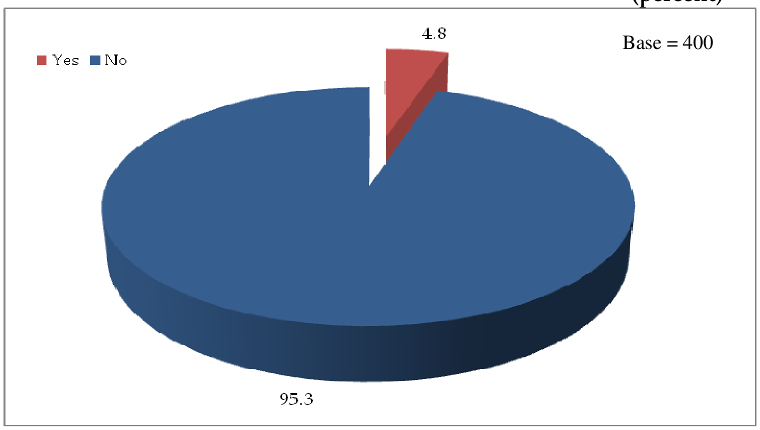


3.5.5 Digital Display Board

When the fishermen were asked about digital display boards, only 5 percent reported that they used the boards to collect weather information. Of the 19 fishermen who use digital display boards, 18 belong to Nagapattanam district of Tamil Nadu.

Figure 3.10: Use of Digital Display Boards among Fishermen

(percent)



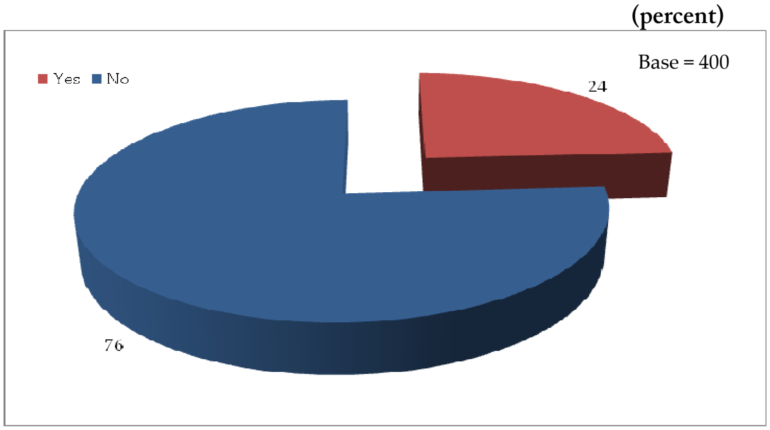
3.6 Future Intentions and Insurance

3.6.1 Willingness to Continue Fishing Operations

In response to the question about their willingness to allow the next generation to take up fishing, three-fourth of the fishermen (76%) reported that they were against it.

Figure 3.11: Willingness to Allow Next Generation to take up Fishing

(percent)

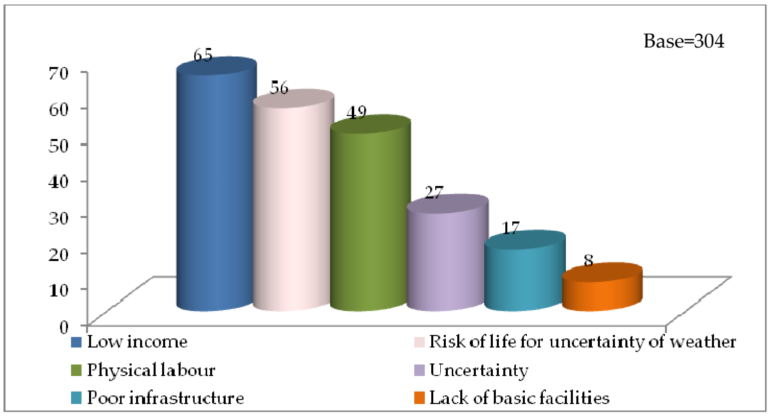


3.6.2 Reasons for not opting next generation's involvement in fishing

The fishermen who reported that they do not want their next generation to take up fishing were asked for their reasons. Their main reasons include low income (65%), risk to life due to weather uncertainties (56%) and physical labour (49%).

Figure 3.12: Reasons for not Wanting Next Generation's Involvement in Fishing

(percent)

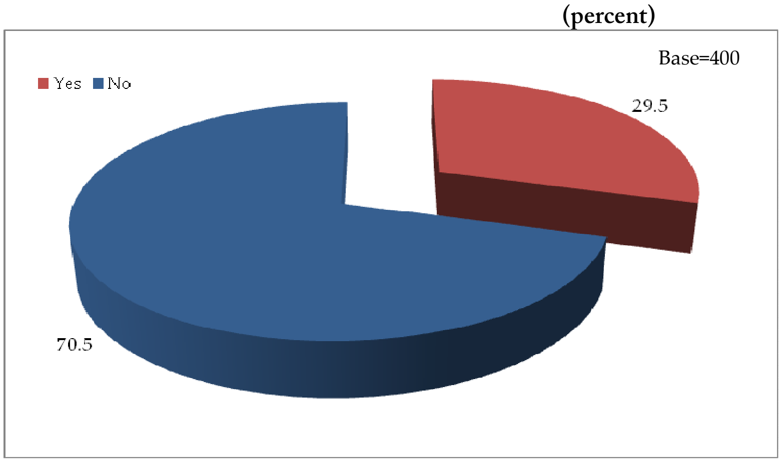


3.6.3 Insurance Coverage

In the present day, the demand for insurance is increasing especially among those whose life is at risk. For this reason the fishermen were asked whether they are insured under any group accidental insurance scheme. Figure 3.13 clearly indicates that about 70% of fishermen are not insured under any such scheme, which highlights the need for insurance for fishermen.

Figure 3.13: Fishermen Insured Under Group Accident Insurance Scheme

(percent)



3.7 MS Swaminathan Research Foundation (MSSRF)

User perceptions about the usefulness/relevance of participation by NGOs, like the MS Swaminathan Research Foundation (MSSRF), Chennai in disseminating weather information was collected through separate FGDs held with farmers and fishermen.

MSSRF, a non-profit research organisation, has been setting up and managing Village Resource Centres (VRC) and Village Knowledge Centres (VKC) to provide need-based, locale-specific and demand-driven information. MSSRF is designed to encourage the development of market-driven on-farm and non-farm enterprises and enable a shift from unskilled to skilled work through the sustainable use of natural resources through the initiative of Village Knowledge Centres (VKCs). The VKCs, which were set up in 1992, are normally located among a cluster of villages or at the Panchayat levels. A Village Resource Centre (VRCs) is typically located at the block level, the commune level or the mandal level or at the central point of a cluster of villages. In 2003 MSSRF established the Jamshedji Tata National Virtual Academy (NVA) to bring together experts and grassroots communities in two-way communication with the objective of making knowledge accessible to every home and hut. This helped strengthen the programmes of VRC and VKC and involved collaboration with international and national partners like ISRO, IFFCO, IKSL, and Tata Trust.

3.7.1 MSSRF – INCOIS

The Indian National Centre for Ocean Information Services (INCOIS) provides ocean data, information and services to society, academics and the government; to improve their coverage Electronic Display Boards (EDBs) have been adapted which facilitate the dissemination of satellite pictures, disaster warnings, and ocean state information in addition to the normal multi-lingual text information. INCOIS and MSSRF have a strategic partnership to this effect. INCOIS has provided 12 digital boards to MSSRF and requires such agencies to take responsibility for the board and to explain the contents in the board. It is expected that in the near future INCOIS will be able to give more species-specific information (on tuna, etc.), which can help fishermen. To incorporate a voice interface, INCOIS is planning to train the local co-ordinators to record the content and install it in EDBs so that fishermen can listen to it.

Box 1: Results of Video Conference with Fisherman Society

Ramanathapuram Fisherman Society

- Receiving weather reports, such as wind speed /tide level/rainfall and PFZ
- This information is useful to the fishermen
- Weather forecast provided for 48 hours and PFZ information updated every 6 hours.
- Announced PFZs are mainly closer to the islands; this is not a suitable place to use fishing nets.
- The fishermen feel that the weather forecast would be more helpful if provided 5 days in advance. It would be helpful during and after fishing to plan their fishing duration and fish drying process.
- Ramanathapuram fishermen use VHF for communication during fishing.

Nagapattinam Fisherman Society

- Receive weather forecast for 48 hrs such as rainfall/wind speed and tide level
- This information is useful to the fishermen
- Fishermen requested a weather forecast for more than 2 days in advance.

- For communication they use mobile phones. It does not get a signal beyond a certain distance (10 km approx). Hence, they are requesting the government to provide VHF and GPS (many fishermen do not have GPS).

Puducherry Fisherman Society

- Receive weather forecast for 48 hrs such as rainfall/wind speed and tide level
- This information is useful to the fishermen.
- Fishermen requested the weather forecast for 3 to 5 days in advance
- For communication they use mobile phones. It does not get a signal beyond a certain distance (10 km approx). Hence, they are requesting the government to provide VHF and GPS (many fishermen do not have GPS).

3.8 Calculation of Economic Benefits from the Identification of PFZ and Macro-Impact of use of PFZ on Marine and Fishery Sector

3.8.1 Current Share of Fishery Sector in National GDP

The current share of the fishery sector in national GDP at current prices is around 0.81 percent; the current share of the marine fishery sector is around 0.41 percent of GDP. The table below details the domestic product from the fishing sector.

Table 3.3: Domestic Product from Fishing (at current prices)

(₹ crore)

Items	2006-07	2007-08	2008-09
Value of output	41897	45681	49891
Inland fish*	20492	22831	24902
Marine fish**	21404	22850	24989
Repairs, maintenance and other operational costs	6532	6822	7455
Gross domestic product**	35365	38859	42436
Less: consumption of fixed capital	4392	4838	5836
Net domestic product	30973	34021	36600
National Gross Domestic product at factor cost at current prices	3941865	4540987	5228650
Share in National GDP	0.90%	0.86%	0.81%

* including subsistence fish

** including domestic product from gathering pearls, shank shells and other sea products

3.8.2 Envisaged Share of Fishery Sector in National GDP by Identifying PFZs

To estimate the envisaged share of the fishery sector in national GDP we consider three scenarios:

Scenario 1: Only mechanised crafts adopt PFZ

Scenario 2: Both mechanised crafts as well as motorised crafts adopt PFZ

Scenario 3: All mechanised crafts, motorised crafts and traditional crafts adopt PFZ

Fishing, when pursued with the help of information provided by INCOIS through the identification of "potential fishing zones", has a net profit (per haul) as given, which results in a quantum jump in landings catch of fish as well as net profits:

Net profit (per haul with PFZ) = cost of total catch (with PFZ) – Total expenditure in fishing operation (with PFZ)

Similar calculations are also made for non-PFZ, which are then compared to the net profit figure with PFZ. It has been found that there is a substantial difference of about ₹ 2,13,840 (per haul) in the net profit calculated for both the zones. The fluctuations in the market price have been eliminated by using the same price irrespective of the amount of the catch for both PFZ and non-PFZ at ₹ 50 per kg. Value added (in ₹ per haul) is also calculated by deducting the fuel cost from the cost of the total catch. Value added increases 319 percent when PFZ parameters are used for fishing.

Table 3.4: Fishing Operations with PEZ and Non-PEZ
(for December 2006)

Details	PFZ	Non PFZ
Name of the boat	MRR-8	MRR-10
Type of fishing	Mech. Ring seine	Mech. Ring seine
Duration of total trip	9 hrs 30 min	7 hrs 15 min
No. of fishing hours	01	01
No. of hauls	01	01
No. of fishermen engaged	37	36
Total catch (kg)	7200	1800
Major species caught	Carangids	Carangids
Approximate cost of total catch (₹) (@ 50 ₹ /kg)	3,60,000	90,000
Total expenditure in fishing operation (₹)	77,600	21,440
• Fuel	5,400	3,240
• Wages	72,000	9,000
Net profit	2,82,400	68,560
Value added (₹)	3,54,600	86,760

Possible Increase in Domestic Product from Fishing due to PFZ

In Kerala detailed studies were carried out to estimate landings from traditional, motorised and mechanised vessels before the tsunami (2004). Landings as per this case study craft-wise are shown below.

Table 3.5: Kerala Case Study

Type of craft	Number	Estimated Landings	Landings Per unit craft (tonnes)	Proportion of Total
Traditional Craft	9,522	9,190	1.0	15.45
Motorised Craft	14,151	18,800	1.3	31.60
Mechanised Craft	5,507	31,508	5.7	52.96

In order to project the share of landings craft-wise at the all-India level, estimates of population of craft category were used as under:

Table 3.6: All-India Estimates of Population of Crafts

Type of craft	Number	Estimated Landings	Proportion of total	Alternative estimate marine fishery (2007)
Traditional Craft	220,000	212,329	37.7%	4%
Motorised Craft	40,000	53,141	9.4%	28%
Mechanised Craft	52,000	297,515	52.8%	68%

The table above shows the results as applied to the estimated population of craft categories. However current estimates of landings craft-wise carried out at the all-India level based on a survey of the marine sector are at variance. The current trend is to convert traditional crafts to motorised crafts and/or to use more motorised crafts instead of traditional crafts.

Going by this observation, in Scenario 1, we have assumed that the share of mechanised vessels to landings could range between 53 percent and 68 percent.

Scenario 1: Only Mechanised Crafts Adopt PFZ

Sl. No.	Particulars	
1	Value of output (2008-09) Fishery Sector is	₹ 49,891 crore
2 2.1	Value of Output Marine Fish (2008-09) Sector is Value added is (85 % of 24,989)	₹ 24,989 crore ₹ 21,241 crore
3	Value of Output Marine Fish (2008-09) from the Mechanised Crafts segment (53% to 68 % of 24,989) is:	₹ 13,244 to ₹ 16,993 crore
4	Value added Marine Fish Sector (Mechanised Vessel) Segment is (85% of Value of Output Marine Fish from the Mechanised Crafts segment):	₹ 11,257 to ₹ 14,444 crore
5	Now value added from the Mechanised vessel sector increases by 309 percent. Increase in Value added is [309 % of Value added Marine Fish Sector (Mechanised Vessel) Segment]:	₹ 34,784 to ₹ 44,632 crore
6	Value added from Mechanised Vessel Sector is (409 % of Value added Marine Fish Sector (Mechanised Vessel) Segment):	₹ 46,041 to ₹ 59,075 crore
7	Total Gross Domestic Product from Marine Fishery Sector is: (Value added from Mechanised Vessel Sector + (0.47 to 0.32) of Value added from Marine Fish + Value added from Inland fish)	₹ 77,191 to ₹ 87,040 crore
8	Ratio to National GDP at factor cost at Current prices: (Total Gross Domestic Product from Marine Fishery Sector/(National GDP at factor cost + Increase in Value added in fishery sector)	1.47 to 1.65 percent

Scenario 2: Both Mechanised Crafts as well as Motorised Crafts Adopt PFZ

Combined share of landing as proportion of total marine landings: 0.62 to 0.96.

Sl. No.	Particulars	
1	Value of output (2008-09) Fishery Sector is:	₹ 49,891 crore
2 2.1	Value of Output Marine Fish (2008-09) Sector is: Value added is (85 % of 24989):	₹ 24,989 crore ₹ 21,241 crore
3	Value of Output Marine Fish (2008-09) from both Mechanised and Motorised Vessels is:	₹ 15,493 to ₹ 23,989 crore
4	Value added Marine Fish Sector (Mechanised and Motorised Vessel) Segment:	₹ 13,169 to ₹ 20,391 crore
5	Now value added from the Mechanised vessel sector increases by 309 percent. Increase in Value added is:	₹ 40,692 to 63,008 crore
6	Value added from Mechanised Vessel Sector is:	₹ 53,862 to ₹ 83,399 crore
7	Total Gross Domestic Product from Marine Fishery Sector is:	₹ 83,100 to ₹ 105,415 crore
8	Ratio to National GDP at factor cost at current prices is:	1.58 to 1.99 percent

Scenario 3: Mechanised Crafts, Motorised Crafts and Traditional Crafts Adopt PFZ

Sl. No.	Particulars	
1	Value of output (2008-09) Fishery Sector is:	₹ 49,891 crore
2 2.1	Value of Output Marine Fish (2008-09) Sector is Value added is (85% of 24,989):	₹ 24,989 crore ₹ 21,241 crore
3	Value of Output Marine Fish (2008-09) from Mechanised Vessels, Motorised Vessels and Traditional Crafts is:	₹ 24,989 crore
4	Value added Marine Fish Sector (Mechanised Vessels, Motorised Vessels and Traditional Crafts) Segment is:	₹ 21,240 crore
5	Increase in Value added due to PFZ is:	₹ 65,633 crore
6	Value added from Mechanised Vessels, Motorised Vessels and Traditional Crafts Sector after adoption of PFZ:	₹ 86,874 crore
7	Total Gross Domestic Product from Marine Fishery Sector is:	₹ 108,041 crore
8	Ratio to National GDP at factor cost at current prices is:	2.04 percent

Export Realisation: In Scenario 1, 2 and 3 currently 21 percent of the catch is exported. We assume that 21 percent of the catch facilitated by PFZ is exported in all three scenarios.

The average export realisation per kilogram during the year 2008-09 was ₹ 145.8. Total export realisation of additional catch scenario would be:

Particulars	
In Scenario 1: [(Extra catch/trip)* No of days* No of Mechanised craft*Average export Realisation* 0.21]	₹ 150,457 crore
Scenario 2	₹ 178,845 to 201,347 crore
Scenario 3	₹ 283,881 to 22,1260 crore
Net Economic Benefit: Premium on foreign Exchange earned valued at 10 percent:	
Scenario 1:	₹ 15,045 crore
Scenario 2:	₹ 17,884 to ₹ 20,134 crore
Scenario 3:	₹ 22,126 crore
Net Economic Benefit: Additional Consumption Benefits and one third of Additional Consumption Benefit treated as Economic gains	
Additional Consumption Benefits: (Increase in Wages due to adoption of PFZ* No of Days* No of Mechanised craft)	₹ 57,330 crore
Economic gains: (one third of Additional Consumption Benefits)	₹ 19,110 crore
Net Combined Economic Benefit in Scenario 1--- (Net Economic Benefit in Scenario 1+ Economic Gain)	₹ 34,155 crore
Net Combined Economic Benefit in Scenario 2	₹ 40,600 to ₹ 45,708 crore
Net Combined Economic Benefit in Scenario 3	₹ 50,229 crore

Table 3.7: Average Import Duty Rates in India (Total)

Commodity Group	1991-92	1992-93	1993-94	1994-95	1995-96	1996-97	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06	2006-07	2007-08	2008-09
Weighted Avg. *																		
Agriculture	68.3	22.5	24.9	28.0	23.8	15.7	24.9	26.8	17.5	13.0	26.2	30.3	34.4	41.7	39.5	64.8	52.0	54.3
Mining	95.5	14.5	19.3	11.9	31.1	22.3	23.9	21.1	21.6	21.0	15.2	10.7	15.3	10.8	6.0	5.6	9.6	9.6
Consumer Goods	114.1	86.3	66.2	62.6	43.5	38.0	34.1	41.0	41.9	57.2	50.7	48.4	57.8	43.7	31.2	29.5	22.2	12.6
Intermediate Goods	65.6	57.6	45.1	51.5	34.9	35.5	34.1	41.0	39.6	37.5	36.1	32.1	28.5	20.5	14.6	12.5	9.9	10.1
Capital Goods	94.8	85.0	49.4	41.6	28.7	30.4	26.1	31.0	33.1	29.8	27.8	25.4	25.3	16.6	9.6	8.5	6.8	6.5
All Commodities	**77.2**	**62.6**	**45.8**	**47.1**	**32.9**	**33.3**	**30.6**	**36.0**	**36.9**	**37.9**	**29.6**	**25.7**	**26.7**	**18.7**	**12.0**	**11.2**	**10.2**	**9.9**

Source: Budget documents for customs and tariffs and DGCI&S for imports, 2009.

3.8.3 Information Dissemination – Fishermen

Fisher Friend: The fisher friend programme builds on a vast network of pre-existing infrastructure and relationships that MSSRF has built up in the fishing communities of Tamil Nadu and neighbouring coastal regions. It provides real-time safety and weather information as well as the location of fishing areas and market prices to fishermen anytime, anywhere at the press of a button. Fishermen are provided specially designed mobile handsets, which cost around ₹ 2,500. All information is gathered in a central server at MSSRF, Chennai. Upon a single button click request from a menu-driven client software on the mobile phone, fishermen get access to vital information in the local language (Tamil) that is simple to understand. As of October 2009, about 200 fishermen were sharing 47 Fisher Friend mobile phones in Puducherry and Tamil Nadu. With this information, fishermen catch a large shoal of fish and save on both diesel and time. Fishermen from neighbouring villages also take their guidance and increase their yield.

Netfish: This is a society under MPEDA[4] that focuses on training and awareness. It trains over 6,000 people in 103 villages in subjects such as sustainable fishing practices, hygienic handling of fish and quality control of fish products. As a result, many fishermen now use the turtle-excluding device and practice sustainable fishing. Fishermen were also sensitised to the need for preserving the rich biodiversity of the Gulf of Mannar, especially the corals, seaweed, sea grasses, turtles and dolphins.

INCOIS Services with Other Sectors: INCOIS also provides information to maritime boards, the Navy, coast guard, shipping and energy sectors, oil industries, etc. To get information from these users, we sent them questionnaires but got responses only from the Gujarat Maritime Board. The Port Department of Andhra Pradesh informed us that they do not use the services of INCOIS; instead, they collect tidal information from the National Institute of Ocean Technology (NIOT), Chennai that has established auto tide gauges both in Kakinada Port and Machilipatam Port to collect tidal information regularly.

[4] MPEDA (Marine Products Export Development Authority) functions under the Ministry of Commerce, Government of India and acts as a co-ordinating agency with different central and state government establishments engaged in fishery production and allied activities.

Box 2: INCOIS Services to Gujarat Maritime Board

1. What type of information does the Indian National Centre for Ocean Information Services (INCOIS) provide?

- Map comprising contour plot (three days in advance at 3-hourly intervals) of significant wave heights (0.6 metre, 1.2 metre, and 2.0 metre. contours) superimposed on bathymetry chart for 10 ports. Mao domain is 19 N to 24 N and 6 E to 73 E.
- Significant wave height, swell and wind data for the specified locations on a daily basis.
- Significant wave height data in tabular format on monthly basis for fixing the I V limits.

2. Whether information provided by Indian National Centre for Ocean Information Services (INCOIS) is accurate, reliable and timely? Y/N (Please specify the reason in both cases): Yes

The significant wave height provided by INCOIS can be utilised for the purpose of granting Voyage and Towing permissions to Vessels under I V Act – 1917 for safe and smooth operation of barges in the Gujarat Coast.

3. How does INCOIS information help in decision making? If yes, please specify with some examples: Yes it helps in Decision Making

For the movement of marine crafts, looking at weather predictions, decisions are taken to permit barge operations for cargo work, hydrograhic survey, voyage and towing permissions, berthing and de-berthing of vessels and predictions of cyclone, etc.

4. Is it feasible for you to get your own information centre? Y/N Please specify the reason: Yes

We have tide gauges and weather station installed at different ports which can also provide data. But being tidal-affected areas and heavy silt movements, these data are not reliable.

CHAPTER IV
Use of Weather Information by Farmers

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

The Ministry of Earth Sciences has set up a network of 130 AMFUs covering the agro-climatic zones of the country. Each agro-climatic zone covers, on average, 4 to 6 districts. These units are operated at State Agriculture Universities (SAUs), the Indian Council of Agricultural Research institutions (ICAR), and Indian Institute of Technology (IIT) by providing grant-in-aid from the IMD. These units are responsible for recording agro-meteorological observations, preparing forecasts based on Agromet advisories for the districts falling under the precinct of the concerned agro-climatic zone and disseminating this information. The concerned university/ institute has appointed Nodal Officers and Technical Officers, who prepare the advisory bulletins in consultation with a panel of experts at these units. The Agromet bulletins include specific advice on field crops, horticultural crops and livestock, etc. which farmers need to act upon. Its frequency is twice a week, on Tuesdays and Fridays.

To meet the growing need for weather services, the government recently launched the District-level Agro-meteorological Advisory Service (DAAS) in June 2008. DAAS aims to generate agro-meteorological information (weather forecast and agromet-advisories) and develop a suitable dissemination system to the farming community in order to improve crop/livestock productivity. It enables farmers to take advantage of benevolent weather and minimise the adverse impact of malevolent weather on crops.

As per the latest arrangements, IMD products, which are the weather forecasts for 612 districts, are disseminated to the regional meteorological centres and the meteorological centres of the IMD located in different states. These offices undertake value addition to the IMD products and communicate it to 130 AMFUs or AAS units who, in turn, prepare district-specific agro advisory bulletins, thereby translating the weather forecasts to advisories. These bulletins are disseminated to the farmers through mass media agencies, information technology processes and extension services. This dissemination of information through bulletins to the farm households is done in the regional language and the forecasts are specific to the location, season, weather, and crop. These bulletins provide an advisory along with the forecast on crop planning, variety selection, selection of proper sowing/harvesting time, irrigation scheduling, pest and disease control operations, fertiliser application, advisory on wildfires through wildfire rating forecasts, livestock management information, etc. Apart from bulletins, the dissemination of the advisories also takes place through All India Radio

(AIR) and Doordarshan, private TV radio channels, newspapers, the Internet, and Kisan Call Centres/ Krishi Vigyan Kendras (KVK)/ District Agriculture Offices (DAO)[5]. In order to communicate Agromet advisories in real time to rural farmers in every district of the country, district-level agromet advisory service meetings are held to develop a mechanism to involve district-level agencies like district agriculture offices, Krishi Vigyan Kendras, Kisan Call Centres, and NGOs to strengthen the Agromet advisory service. The AMFUs or AAS units also conducted public awareness programmes to educate farmers about the use of agro advisories in farm operations through mass media such as TV, radio, and the press and also through *kisan melas*. However, the outreach of the DAAS system at the block and Panchayat (village) level in a timely manner needs to be stepped up since there is a wide information gap between the information generator and the user. One of the main problems in dissemination of information is that the AAS information published electronically by IMD rarely reaches the farmer due to limited access to the Internet. In this regard, the Common Service Centres (CSC) of the Department of Information Technology (DIT) is a good solution and has witnessed incremental use in the dissemination of information in the recent past. The IMD and DIT are thus working to extend agro-met services through these CSCs to provide meteorological information linked with agri-productivity measures like farming inputs/ precautions/ package of practices in terms of information and guidance. It also provides weather warnings to ensure minimal losses due to disasters. It is like establishing a two-way communication linkage through CSCs so that agri-related queries can be addressed. Training may also be planned for the operators of these centres as well as farmers on the use of Agromet advisories in farm management through AMFUs with active support from the IMD/ ICAR. Public-private partnership models, which are economically viable yet farmer-friendly, have also been suggested to promote ICT participation for transfer of information to the farmer and for efficient dissemination of climate information to the farmer.

This chapter provides the findings on awareness and use of weather information among farmers. The findings are presented under two broad heads, *viz*., farmers living in districts with Agro-Met Field Units (AMFU) and districts without Agro-Met Field Units (non-AMFU).

4.1 Source and Use of Weather Information

Farmers were asked whether they receive weather information. One-fourth of farmers in each set of districts, i.e., districts with AMFU and districts without AMFU, reported the same.

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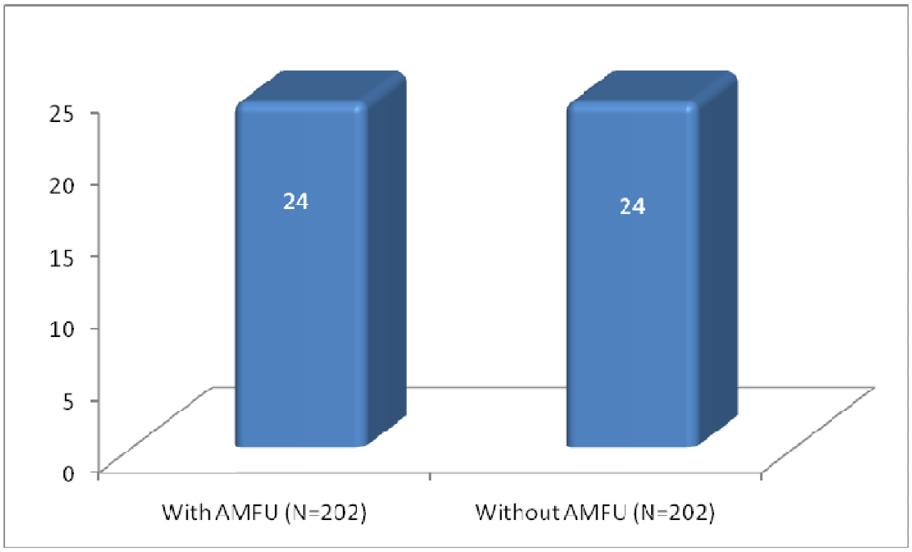
[5] "Telecentres" are increasingly being seen as a means to provide a wide range of telecommunication services to rural residents through a single access point. Multi-Purpose Community Telecentres (MCTs) have been established in various countries in Africa, Asia and Latin America by the International Telecommunication Union (ITU), with various national and international partners. Located in a shared rural community facility, MCTs can offer telecommunication services such as telephone, fax, e-mail and internet access along with training and support in their use. In the design of MCTs, attention is being given to specific applications and content for several sectors, for example; health, education, environmental protection, and agriculture.

Figure 4.1: Percentage of Farmers Receiving Weather Information



4.1.1 Sources of Weather Information

Farmers who reported receiving weather information were probed about the source from which they receive it. 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 4.1).

Table 4.1: Sources of Weather Information

(percent)

Source	With AMFU	Without AMFU
All India Radio	12.2	32.0
TV	75.5	74.0
Krishi Darshan	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 N	**49**	**50**

Note: Total exceeds 100 due to multiple responses.

4.1.2 Frequency of Use of Weather Information

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 daily, while using the TV daily was reported by nearly half the farmers in districts with AMFU and more than three-fifth in districts without AMFU. 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 (Table 4.2).

Table 4.2: Frequency of Weather Information Use

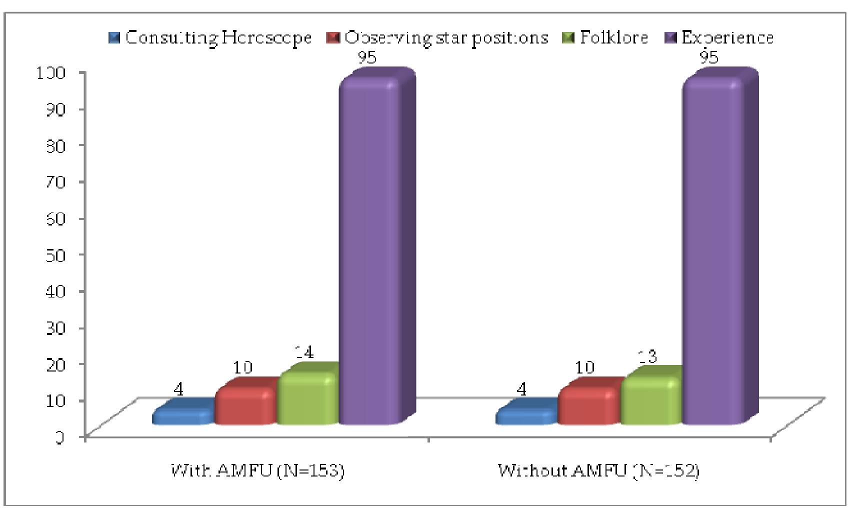
(percent)

	With AMFU	Without AMFU
All India Radio		
Daily	50.0	81.3
Once weekly	33.3	6.3
Twice weekly	16.7	0.0
Once a month	0.0	6.3
Occasionally	0.0	6.3
Total	**6.0**	**16.0**
TV		
Daily	45.9	62.2
Once weekly	18.9	10.8
Twice weekly	16.2	5.4
Once a month	0	2.7
Occasionally	16.2	16.2
No response	2.7	2.7
Total	**37.0**	**37.0**
Krishi Darshan		
Daily	31.8	48.0
Once weekly	18.2	20.0
Twice weekly	13.6	8.0
Once a month	9.1	0.0
Occasionally	27.3	24.0
Total	**22.0**	**25.0**

4.1.3 Traditional Methods of Weather Forecast used in Farming

The farmers who do not receive any weather information were probed about the traditional methods of weather forecast used in farming. Findings show that most (95%) of the farmers in both AMFU and non-AMFU districts reported using the experience of self and elders for weather forecasting. One-sixth of the farmers in both types of districts reported following folklore for the same.

Figure 4.2: Categories of Traditional Methods Used in Agriculture in AMFU and non-AMFU Districts



4.1.4 Operations where Weather Information is Used

The farmers who receive weather information were asked about the areas/ operations where they use weather information. The findings show that the top operations in which farmers in districts with AMFU use weather information 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 (Table 4.3).

Table 4.3: Operations where Weather Information is Used

(percent)

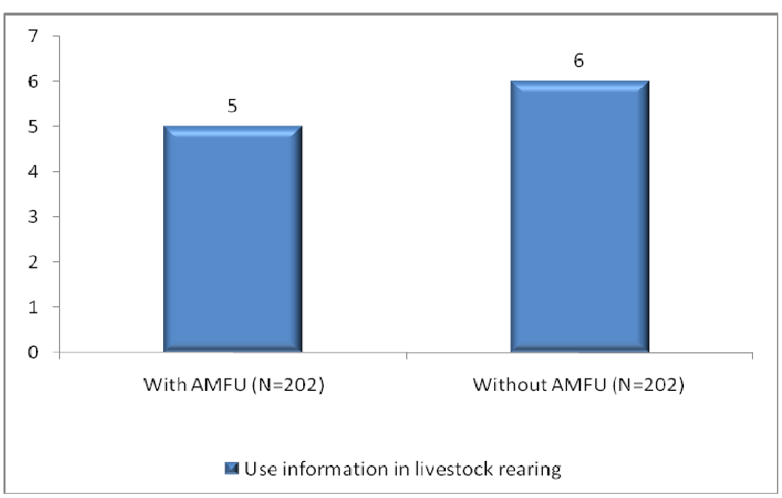
Operations	With AMFU	Without AMFU
Cropping pattern	59.2	83.7
Sowing and harvesting	73.5	75.5
Scheduling irrigation	53.1	69.4
Mitigation in moisture stress	28.6	30.6
Fertiliser application	51.0	53.1
Spraying pesticides	71.4	63.3
Dairy, hatchery, etc.	12.2	14.3
Market-related decisions	22.4	24.5
Buying machines	10.2	18.4
No response	2.0	0.0
Total N	**49**	**49**

Note: Total exceeds 100 due to multiple responses.

4.1.5 Use of Weather Information in Livestock Rearing

Figure 4.3 gives the findings on the use of weather information in livestock rearing by the farmers. Less than one-tenth each in districts with AMFU and districts without AMFU reported the same.

Figure 4.3: Percentage of Farmers using Information in Livestock Rearing



4.1.6 Reasons for not using Weather Information in Livestock Rearing

The farmers who do not use weather information in livestock rearing were probed for the reasons. More than one-fourth of the farmers from both sets of districts reported that they do not need the information while one-fourth each reported not having a source of information. About one-sixth of the farmers use their own experience for animal husbandry (Table 4.4).

Table 4.4: Reasons for Not Using Weather Information in Livestock Rearing

(percent)

	With AMFU	Without AMFU
Reason		
Don't have source of information	23.8	24.3
No need	28.7	27.2
Own experience	14.9	12.9
Don't have time	1.5	0.5
Get information from village	1.0	0.0
Don't know/ can't say	6.4	5.0
No response	7.9	15.3
Total N	**202**	**202**

Note: Total exceeds 100 due to multiple responses.

4.2 Usefulness of Weather Information

4.2.1 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 findings presented in this section are based on the general perception/experience of farmers.

The pattern that emerges from the analysis reflects that the relation between reducing cost and increasing income is the same in operations like cropping patterns, sowing and harvesting, market-related decisions and buying machines in districts with AMFU. Around two-fifth each of the farmers in districts with AMFU reported increases in income in scheduling irrigation and fertiliser application. The majority (86%) of the farmers in districts without AMFU reported increased income in cropping patterns as compared to two-third in districts with AMFU (Table 4.5).

The overall findings suggest that AMF units do not make any significant contribution to reducing cost and increasing income, as the districts without AMFU also perform well in terms of percentage points. However, weather forecast and information seem to make a very significant contribution in reducing cost and increasing income in different farming operations.

Table 4.5: Benefit of Weather Information in Different Operations

(percent)

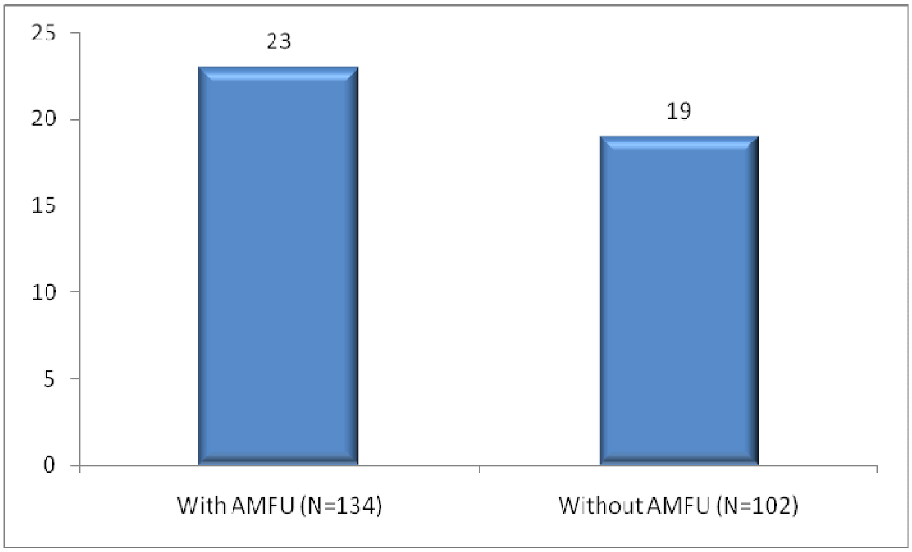
	With AMFU	Without AMFU
Cropping Patterns		
Reducing cost	63.3	71.4
Increasing income	63.3	85.7
Sowing and harvesting		
Reducing cost	61.2	71.4
Increasing income	61.2	75.5
Scheduling irrigation		
Reducing cost	55.1	57.1
Increasing income	61.2	63.3
Mitigation in moisture stress		
Reducing cost	26.5	20.4
Increasing income	28.6	26.5
Fertiliser application		
Reducing cost	51.0	55.1
Increasing income	57.1	61.2
Spraying pesticides		
Reducing cost	55.1	59.2
Increasing income	57.1	59.2
Dairy, hatchery, etc.		
Reducing cost	6.1	10.2
Increasing income	12.2	12.2
Market-related decisions		
Reducing cost	18.4	22.4
Increasing income	18.4	26.5
Buying machines		
Reducing cost	12.2	12.2
Increasing income	12.2	14.3
Total N	**49.0**	**49.0**

4.2.2 Importance of Weather Information in Making Profits

Farmers in both AMFU and non-AMFU districts were asked whether they have used weather advisories for seasonal planning and for selection of crops. 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 (Figure 4.4) which highlights the contribution of AMF units.

Figure 4.4: Percentage of Farmers Reporting Weather Information helped make Profit (in past five years)



4.2.3 Value of Weather Information

The farmers were asked to rate the weather information in terms of its helpfulness and reliability. 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 (Table 4.6).

Table 4.6: Perceptions about Reliability and Helpfulness of Weather Information

(percent)

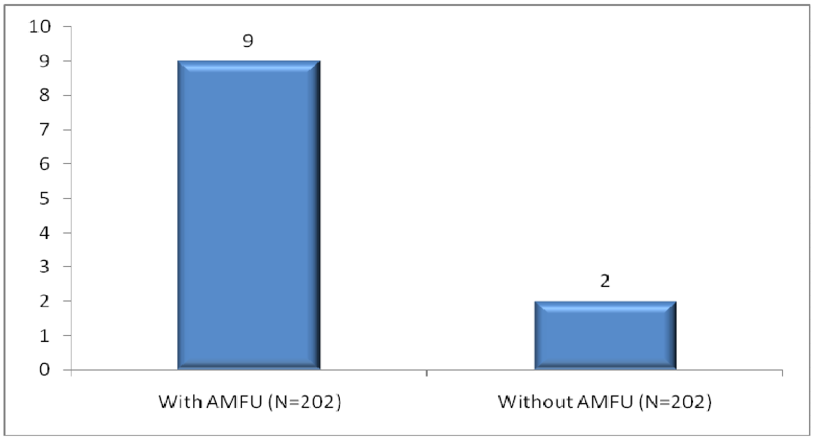
	With AMFU	Without AMFU
Strongly agree	24.5	26.0
Agree	46.9	30.0
Neutral	20.4	16.0
Disagree	8.2	22.0
Strongly disagree	0.0	6.0
Total N	**49.0**	**50.0**

The reasons why farmers in both types of districts feeling that weather information is not helpful are:

- The information was not needed as one knows how to deal with the problem
- They could not understand the information and
- The information was not timely

Figure 4.5 gives the findings on whether the use of weather information helped reduce costs during stress or other periods. One-tenth of the farmers in districts with AMFU and only 2 percent of the farmers in districts without AMFU reported the same. This also highlights the importance of weather information in farming.

Figure 4.5: Percentage of Farmers Reporting Information Helped Reduce Costs during Stress or Other Period



4.3 Awareness of Services

Farmers were asked about their awareness of various services. Their responses are shown in Table 4.7. Awareness of the bulletin of the Agro Advisory Services (AAS) is very low among farmers in both sets of districts. Less than one-tenth of the farmers reported being aware of individual interaction of AAS/ other agencies or the Common Service Centre (CSC).

Table 4.7: Farmer Awareness of Services

(percent)

	With AMFU	Without AMFU
Awareness of Bulletin of Agro Advisory Services (AAS)	5.0	5.4
Awareness of Individual Interaction of AAS/ Other Agencies	3.5	4.0
Awareness of Common Service Centres (CSC)	3.5	4.0
Total N	**202**	**202**

4.4 Suggestions for Receiving Weather Information

4.4.1 Farmers willing to Pay more for Information

Farmers were asked whether they would be willing to pay more for detailed weather information, the source of this information and the kind of information they would like to receive. The findings are presented in Figure 4.6 and Table 4.8.

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. Their 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% each of the farmers in districts with and without AMFU. TV and radio are also 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%).

Figure 4.6: Percentage of Farmers Willing to Pay More for Detailed Information

Table 4.8: Preferred Sources and Areas of Information

(percent)

	With AMFU	Without AMFU
Source		
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**

Thus we have observed that while the 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. Some of the key bottlenecks of the current system include:

- At the policy level, the focus on development of agro-meteorological services lacks the intensity and drive required to handle the massive challenge that the weather poses to Indian agriculture. With just about 130 Agro-Meteorological Field Units (AMFUs) 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 district-level AAS 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 rarely reaches the farmer due to limited access to the Internet.
- Research and development in agro-climatology is found wanting in applied research and farmer interaction. Private sector participation in institutional capacity building is extremely low.

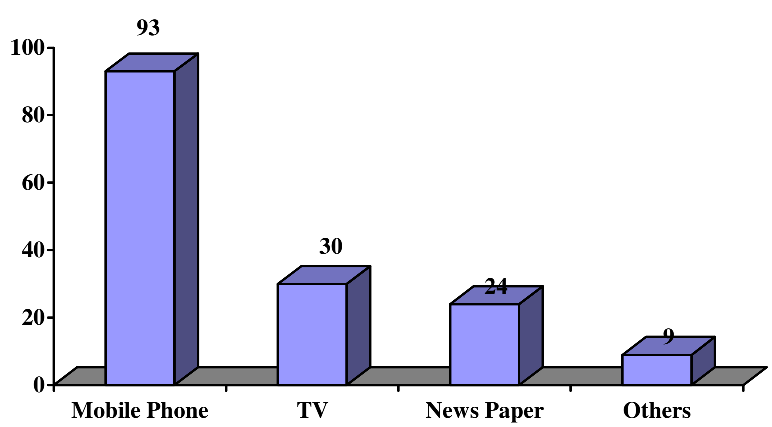
4.5 Use of Mobile Phones to Receive Weather Forecasts

As discussed in Chapter 2, in the farmer segment 171 farmers were interviewed over the telephone to assess the usefulness of mobile phones in providing weather information. Farmers from Madhya Pradesh, Punjab, Uttar Pradesh, Gujarat and Maharashtra were interviewed over the telephone. The findings pertaining to these are presented in this section.

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.

Figure 4.7: Farmers using Different Sources for Weather Information

(percent)



During the telephone interviews, the farmers were also asked how long they have been using mobile phones to get weather information. The analysis of data reveals that, on average, farmers have been using phones for the past 1½ years for this service. About half the farmers (49%) have used mobiles for less than one year to receive weather information.

Table 4.9: Duration of Using Mobile Phones for Weather Information

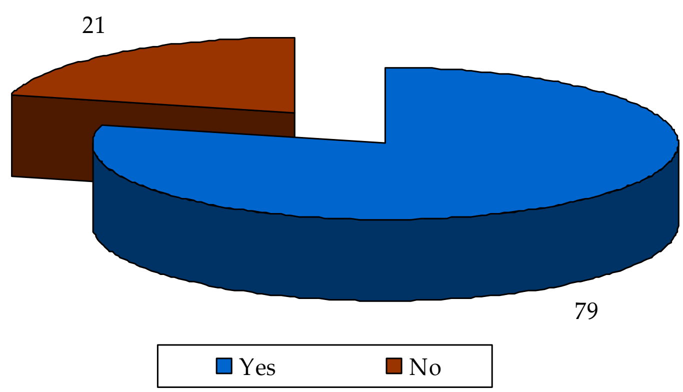
(percent)

Length of time mobile phone has been used for weather information (in years)	Percent farmers
Less than 1 year	48.5
1 - 2 years	31.6
More than 2 years	19.9
Mean	1.4
Total N	**171**

4.5.1 Usefulness and Type of Information

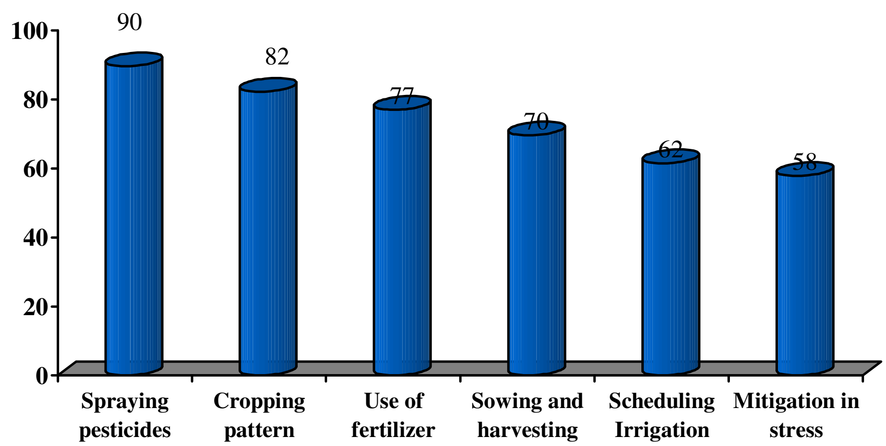
In response to the question on the usefulness of weather information provided on mobile phones, about four-fifth (79%) of the farmers feel that the information is useful for their farming. Those who reported that the information is not useful were probed for their reasons. Of the 35 such farmers, three-fifth feel that the information is not reliable. Similarly, about one-fourth (23%) reported that they believe in traditional knowledge.

Figure 4.8: Farmers Opinions on Usefulness of Weather Information provided through Mobile Phones



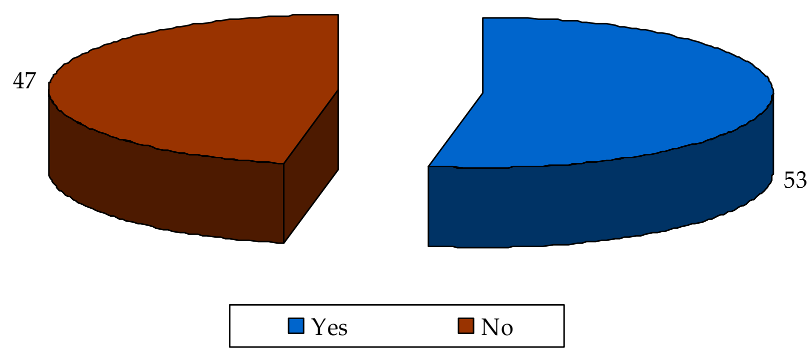
Farmers who reported that the information received through mobile phones was useful were asked about the type of information they receive. Almost all the farmers receive information on spraying pesticides. More than three-fourth of the farmers also receive information on cropping patterns (82%) and use of fertilisers (77%) in farming (Figure 4.9).

Figure 4.9: Type of Information Received through Mobile Phones



To find the sustainability of the method of information dissemination through mobile phones, the farmers were asked whether they would pay more to get information on mobile phones. The analysis suggests that almost half the farmers are not interested in paying more to receive such services.

Figure 4.10: Farmers' Willingness to Pay more for Information on Mobile Phones



4.6 Calculation of Economic Benefits to Farmers

Scenario 1: Awareness Limited to 24 percent Farmers

Economic profit derived by farmers through the use of the weather information provided by the IMD was calculated with the help of the 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 were receiving weather information. The results point to the fact that of these farmers only 58% could make a profit from the information provided. "Economic profit" was calculated 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)

Crops that were considered for the study were paddy, wheat, maize, cotton, gram, soya bean, jawar, sugarcane, mustard, bajra, tobacco and groundnut. Total production figures reported by the farmers is in million tons for the year 2009-10, while average profit is reported in ₹ per ton. Total farmers financial profit (see the table below) through calculations comes to ₹ 44321 crore. Similarly the total farmers' financial profit will be ₹ 92,335 crore when 50% of the farmers are aware of the weather information. If the awareness increases to 100% then the farmers' financial benefit will be ₹ 184,671 crore.

Financial gains occurring to farmers that can be attributed to accurate weather forecasts and the associated appropriate agro-advisory services have been obtained from field surveys; these financial gains to the farmers' community (considered a "reference group" in this study) have been converted to economic gains using crop-wise conversion factors [ratio to international prices (World Bank) to MSP].

Table 4.10A: Farmers' Profit from the Use of Weather Information

Crop	Average Profit in ₹ /ton	Total Production (million tons) in 2009-10	Farmers' Profit (₹ crore) Scenario 1 (Awareness limited to 24% farmers)	Farmers' Profit (₹ crore) Scenario 2 (Awareness limited to 50% farmers)	Farmers' Profit (₹ 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.

Table 4.10B: Farmers' Profit and Economic Profit from the Use of Weather Information

Crop	Farmers' Profit (₹ crore)			Conversion Factor	Economic Profit (₹ 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.

4.7 Recommendations and the Way Forward

Though policymakers have initiated actions to address the impact of weather change on agriculture, more focus is required to address the challenges of weather on Indian agriculture. The first step in this direction would be to develop a comprehensive policy and action plan that assesses various scenarios of the possible impact of climate change on agriculture. Other key interventions that require specific attention include:

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 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 climate information to the farmer.

Promoting Private Participation in Agro-meteorology: While there are several private players who offer niche weather-based services in the sector such as the National Collateral Management Services Limited (NCMSL), Weather Risk Management Services (WRMS) and Skymet, lack of scale and economic viability restrict the entry of private players into the sector. The government needs to develop collaborative partnership models and provide incentives for the entry of private players into this sector during the initial phases.

Supporting Transfer of World-class Technology to India: There are many global technologies linking agro-meteorology to scientific yield management of crops. For instance, a Dutch firm provides an automated weather station (linked via satellite) in the farm which monitors water usage by plants, evaporation, humidity, wind, rainfall, temperature, etc. to judge crop conditions and give timely advice to the farm owner on decisions related to activities such as sowing, irrigation, fertiliser application, pest control and harvesting time. The company claims that farmers achieve up to 30 percent more crop output while reducing input usage. 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.

While many institutions such as IMD, NCMRWF, IITM (Indian Institute of Tropical Meteorology), 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.

CHAPTER V

Awareness and Use of Early Cyclone Warning Information among the General Population

Low atmospheric pressure results in the creation of a cyclone, which involves the inward movement of strong winds. The movement of these winds can be either clockwise or anti-clockwise depending upon their point of origin. Tropical, extra-tropical, subtropical, polar cyclones and mesocyclones are types of cyclone that are prevalent in cyclone-prone areas of the world. A full-grown cyclone is a violent whirl in the atmosphere, 100 to 1000 km across, 10 to 15 km high, with gale winds of 150 to 250 km per hour or more, spiralling around the centre where the pressure may be 30 to 100 hPa. below normal sea-level pressure. Cyclonic storms cause heavy rains, strong winds and high seas, and devastate coastal areas at the time of landfall, leading to loss of life and property (Table 5.1).

Table 5.1: Disturbances Related to Low Pressure Systems

S. No.	Low pressure system	Maximum sustained winds	
1	Low	< 17 knots	< 31 kmph
2	Depression	17 – 27 kts	31 – 51 kmph
3	Deep Depression	28 – 33 kts	52 – 62 kmph
4	Cyclone	34 – 47 kts	63 – 87 kmph
5	Severe Cyclone	48 – 63 kts	88 – 117 kmph
6	Very Severe Cyclone	64 – 119 kts	118 – 221 kmph
7	Super Cyclone	120 kts and above	222 kmph and above

Note: 1 Knot= 1.86 km per hour.

In India, cyclones affect coastal areas every year. A low pressure system forms over the warm ocean surface in which very strong winds circulate around the centre of the system in an anti-clockwise direction. A particular kind of intense vortex known as a tornado also occasionally (average less than one a year) has been observed in parts of east and north-east India during the pre-monsoon months.

The average life span of a cyclonic storm over the north Indian Ocean is about 4 -5 days, which can be divided into four stages: formative stage, immature stage, mature stage, and decaying stage.

The *Formative Stage* covers the period from the genesis of a cyclonic circulation to the cyclonic storm stage through low pressure, depression and deep depression stages. In general, cyclogenesis occurs over warm oceanic regions away from the equator, where the moist air converges and weak vertical wind shear prevails. In the *Immature Stage*, the central pressure of the system continues to fall till the lowest pressure is attained and wind speed increases to very cyclonic storm (>117 kmph), usually at a distance of about 50 km from the centre and a well-developed eye wall[6] is seen. During the *Mature*

[6] The eye is the most spectacular part of a mature cyclonic storm, which forms at the centre of the storm inside a Central Dense Overcast (CDO) region. The eye is surrounded by a 10-15 km thick wall of connective clouds where the maximum winds occur. This is the most dangerous part of a cyclone storm.

Stage, no further fall of pressure or increase of wind speed occur. In the *Decaying Stage*, the tropical storm begin to lose its intensity when it moves over to land, over colder water or lies under an unfavourable large-scale flow aloft. The storm weakens over land because of the sharp reduction of moisture supply and increase in surface friction.

5.1 Studying the Impact of a Cyclone

The impact of a cyclone depends on a single meteorological parameter, *viz*., the horizontal component of maximum wind. The absolute risk due to a cyclone is a multiplicative function of the hazard potential and vulnerability of a community. Therefore, apart from the intensity of the storm the vulnerability to a cyclone depends on factors like coastal topography, population density, type of infrastructure, and seasonal frequency of cyclones.

To quantify this coastal vulnerability, a vulnerability parameter is defined as the product of three main contributing factors: coastal population density, the coastal topography and the annual cyclone frequency. Symbolically, Vulnerability Parameter (VP) = F*T*P, where F is cyclone frequency, T is the coastal topography and P is the population per unit square kilometre. The factors causing loss or damage are winds, heavy rains and storm surges where the highest weightage of incurring loss is given to storm surge.

5.2 Damages Associated with Different Types of Cyclonic Storms

Cyclonic storms are classified according to the wind speed around the circulation centre and, accordingly, the damages are associated. Disturbances related to low pressure systems leading to different type of storms are explained below.

5.2.1 Cyclonic Storms

The wind strength associated with cyclonic storm is 63-87 kmph (as can also be seen from Table 5.1) and the sea wave height is generally 6-9 metres. These storms generally cause damage to thatched houses, *kuchcha* structures/houses, paddy crops and banana/papaya orchards. They can cause inundation of low-lying areas close to the coast. Overall damage under this category of cyclone is minor to moderate.

5.2.2 Severe Cyclonic Storm

Under this category wind speed is in the range from 88 to 117 kmph. The sea wave height is generally between 9 and 14 metres and the storm surge is up to 1.5 metres. Overall damage is considered as moderate. It can damage embankments and inundate low-lying areas up to 5 km. into the coastal region.

5.2.3 Very Severe Cyclone Storm (over the Bay of Bengal)

Wind speed is in the range of 118-167 kmph. The sea wave height is generally more than 14 metres and storm surge up to 2 metres. Overall damage under this category of storm is considered as large. It can inundate coastal areas up to 10 km inland. These storms can destroy thatched houses, *kuchcha* houses and can also damage *pucca* houses. They can create potential threats from flying objects.

5.2.4 Very Severe Cyclonic Storm (over the Arabian Sea)

The expected wind speed varies from 168-221 kmph, the height of the sea waves is generally above 14 metres and the storm surge varies from 3 to 5 metres but it is site-specific. The damage under this category of cyclone is likely to be extensive. Inundation can occur in the coastal region up to a distance of 15 km and the resultant damage can be extensive.

5.2.5 Super Cyclonic Storm

Here the wind speed exceeds 222 kmph and the sea wave height exceeds 14 metres while the site-specific storm surge exceeds 5 metres. Damage under this category of cyclone is catastrophic. It can cause extensive beach erosion.

5.3 Factors Associated with Tropical Cyclones

The factors associated with tropical cyclones or three elements which cause destruction are:

Winds: The damage produced by winds is extensive and covers areas occasionally greater than the areas of heavy rains and storm surges which are generally localised in nature. The torques imposed by the wind can twist the vegetation or even structures. Parts of structures that were loosened or weakened by the winds from one direction are subsequently severely damaged or blown down when hit by strong winds from the opposite direction.

Rainfall: Rains associated with cyclones cause serious damage and give rise to unprecedented floods. Rainfall is generally very heavy and spread over a large area, which leads to flooding. Soil erosion also occurs on a large scale and contributes to weakening the embankments, the leaning over of utility poles or collapse of pole-type structures.

Storm surge: The surge is generated due to the interaction of sea, air and land. When the cyclone approaches the coast, it provides additional force in the form of a very high horizontal atmospheric pressure gradient which leads to surface winds. As a result, the sea level rises as the cyclone moves over shallower water and reaches a maximum on the coast near the point of landfall. Huge volumes of water carrying sand and gravel can cause such pressure differences that the house 'floats' and, once the house is lifted from the foundations, water enters the structure which eventually collapses.

This clearly explains the damage caused by different agents of a cyclone like wind, storm surges and rainfall. To limit this damage, the IMD, the nodal agency of the Government of India, is supposed to issue cyclone warnings in the country and develop an effective and credible cyclone warning system to monitor cyclone development and movement. Table 5.2 gives the record of devastating cyclonic storms in India since 1942.

Table 5.2: Devastating Cyclonic Storms that formed in the Bay of Bengal and made Landfall in the East and West Coasts of India since 1942

S. No.	Date/Year	Category of cyclone	Landfall and other information
1	14-16 Oct, 1942	Severe cyclonic storm	Crossed West Bengal coast near Contai People killed – 19,000 Cattle head killed – 60,000
2	18-23 Nov, 1948	Severe cyclonic storm	Crossed Virar, 72 km north of Mumbai Heavy loss of life and property
3	23-25 May, 1961	Severe cyclonic storm	Crossed Devgad 1,700 houses completely damaged, 2,5000 houses partially damaged
4	26-30 Oct, 1961	Severe cyclonic storm	Crossed Orissa coast near Paradip People killed – 10,000 Cattle head killed – 50,000 Houses damaged- 8,000,000
5	9-13 June, 1964	Severe cyclonic storm	Crossed Naliya, Dwarka and Porbandar People killed-27
6	8-11 Oct, 1967	Severe cyclonic storm	Crossed Orissa coast Oct. 9 and Bangladesh coast Oct. 10-11 People killed – 1,000 Cattle head killed – 50,000 Property of few crore of rupees
7	19-24 Oct, 1975	Very severe cyclonic storm	Crossed Saurashtra People killed-85 Loss of property- ₹ 75 crores
8	31 May - 5 June, 1976	Severe cyclonic storm	Crossed Saurashtra near Bhavnagar People killed-70 Cattle head lost-4,500 Loss- ₹ 3 crore
9	14-20 Nov, 1977	Super Cyclone	Crossed Andhra coast near Nizampatnam People killed – 10,000 Cattle head killed – 27,000 Property and crops – ₹ 350 crore
10	13-23 Nov, 1977	Very severe cyclonic storm	Crossed Mangalore and Honavar People killed-72 Loss- ₹ 10 crore
11	4-9 Nov, 1982	Very severe cyclonic storm	Crossed Saurashtra People killed- 507 Livestock perished – ₹ 1.5 lakh
12	4-11 May, 1990	Super Cyclone	Crossed Andhra coast at Machilipatnam People killed – 967 Property and crops- ₹ 2,248 crore
13	17-20 June, 1996	Severe cyclonic storm	Crossed south Gujarat coast People killed - NA Cattle head perished-2,113 Property loss- ₹ 1,805 lakh
14	5-6 Nov, 1996	Very severe cyclonic storm	Crossed Andhra coast near Kakinada People killed – 2,000 Loss of crops-150
15	4-10 June, 1998	Very severe cyclonic storm	Crossed Gujarat coast near Porbandar People killed-1,173, Missing -1,174 Loss of property- ₹ 1,865.83 crore
16	25-31 Oct, 1999	Super Cyclone	Crossed Orissa coast near Paradip People killed – 9,885 Cattle head killed – 370,297

Historical records of cyclonic storms in the east and west coast of India reveal that the coastal regions of West Bengal, Orissa, Andhra Pradesh on the east coast and Mumbai (Maharashtra), Saurashtra and Porbandar (Gujarat) and Mangalore (Karnataka) on the west coast are prone to cyclones. However, the east coast remains more vulnerable to cyclones than the west coast. The review of the impact on life and property shows that the highest loss of human life was in the severe cyclone storm of 14-16 Oct, 1942 which crossed the West Bengal coast near Contai. Studies reveal that the West Bengal-Bangladesh coastal area is a "very high risk area" due to its population density, while Orissa has a moderate risk due to its relatively lower population and number of coastal installations. The district-wise distribution of cyclone storms shows that along the east coast the Orissa coast is most vulnerable to cyclonic storms, and on the west coast Gujarat is the most vulnerable. The Probable Maximum Storm Surge (PMSS) is largest on the West Bengal coast followed by Gopalpur in Orissa and then by Kavali on the Andhra Pradesh coast. Though in West Bengal the vulnerability of storm surge is high, the death toll in India is lower than in Bangladesh, mainly due to the coastal configuration and the local bathymetry. The height of coastal area of Bangladesh is not much above sea level and the sea near those areas is very shallow, causing greater storm surges that result in inundation of more sea water.

5.4 Cyclonic Disturbances over the Indian Ocean

Only about 15% of the world's tropical cyclones occur in the northern Indian Ocean, but because of the high population densities along low-lying coastlines, the storms have caused nearly 80% of cyclone-related deaths around the world[7]. There are two main problems in the prediction of cyclonic storms in this area. One is incomplete atmospheric data for the Bay of Bengal and the Arabian Sea, which are considered as part of the Indian Ocean, which makes it difficult for regional forecasters to provide warnings well in time for mass evacuations[8]. Second, cyclones particularly in the Bay of Bengal are difficult to analyse because of the "blind spots" in available atmospheric data for individual storms[9]. Land-based weather stations monitor the edges of the bay, but they cannot see much when the storm is brewing several hundred miles away from the coastline. The small dimensions of the bay ensure that storms do not have much time to develop and circulate. Hence, when tropical cyclones form, flooding waves and storm surges can quickly reach the narrow basin's shores. And the wind shear, which is fuelled by large temperature contrasts between sea and land, can lead to erratic storm tracks.

[7] In the absence of observations over the north Indian Ocean, the best track of a cyclone is mostly estimated with the help of satellite imagery interpretation known as Dvorak's technique. This is a subjective technique used to estimate cyclone intensity. However, this technique has been developed for the North Atlantic Ocean basin and needs to be validated for the north Indian Ocean. Further, automated Dvorak's technique has to be developed for the north Indian Ocean to minimise human error based on aircraft reconnaissance. The intensity of the cyclone in this technique is measured through a T. No. which varies from T 1.0 to T 8.0 at intervals of 0.5.

[8] The year-to-year variation is quite large. Minimum No. of cyclones in a year - One (1949), Maximum No. of cyclones in a year – Ten (1893, 1926, 1930, 1976)

[9] The Bay of Bengal is a vast warm pool adjoining the warm pool of the western North Pacific. Also, the ocean currents in the Bay of Bengal are quite complex, which makes the ratio of tropical cyclones between the Bay of Bengal and the Arabian Sea 4:1.

5.5 Cyclone Warning Organisation

The organisation blends scientific conceptual models, meteorological datasets, technology and expertise towards the goal of providing clear, concise, useful and relevant warning information to special users and the public in a timely and effective manner. The best effect of the warning system requires strategic measure in the following aspects:

- Design
- Presentation
- Operation
- Dissemination, and
- Communication of the warning.

The end user communities for the warning are the armed forces, civil security, sports events, tourism, media, shipping, oil industry, agriculture, civil works, industries, energy providers, fishing and others.

5.5.1 Infrastructure in India to Avoid Losses from Cyclonic Storms

India is highly vulnerable to natural hazards on account of its unique geo-climatic conditions, which makes 8% of its coastal area prone to cyclones. As has been seen, the whole of the east coast and the Gujarat coast in the west of India are highly vulnerable. To curtail these losses, the Indian Cyclone Disaster Prevention and Mitigation Plan at IMD consists of the following components:

- Cyclone forecasting and warning service.
- Rapid dissemination of warnings to government agencies, marine interests like ports, fishery and shipping and to the general public.
- Organisations to construct cyclone shelters in cyclone-prone areas and ready machinery for evacuation of people to safer areas.
- Community preparedness at all levels to meet the exigencies

To control the losses arising from a cyclone a similar plan was in place in Myanmar (as is apparent from the cyclone *Nargis*, a case study of which comes later in the chapter). However, because of lack of proper infrastructure, the damage could not be controlled.

The Cyclone Warning Organisation of the IMD consist of six Cyclone Warning Centres located at Kolkata, Bhubaneswar, Chennai, Mumbai, Vishakhapatnam and Ahmadabad which give information to the IMD on the location, intensity and probable track of the cyclone. The work is supervised and co-ordinated by the Forecasting Division at Pune. To co-ordinate and supervise the cyclone warning work in the country, a Cyclone Warning Division has been set up at New Delhi at the headquarters. The Regional Specialised Meteorological Centre (RSMC) for tropical cyclones, New Delhi which is co-located with the Cyclone Warning Division has the responsibility of issuing Tropical Weather Outlook and Tropical Cyclone Advisories for the benefit of countries in the World Meteorological Organization (WMO)/ Economic and Social Cooperation for Asia and the Pacific (ESCAP) and panel countries consisting of Bangladesh, Maldives, Myanmar, Pakistan, Sultanate of Oman, Sri Lanka and Thailand.

The IMD maintains a good network of observatories (at surface, upper air and space levels), covering the entire coastline and islands. Surface weather observations of atmospheric pressure, temperature, wind speed and direction, humidity, and precipitation are made near the earth's surface by automatic weather stations (AWS). Measurements of temperature, humidity and wind above the surface are found by launching radiosondes on weather balloons. In recent years, data transmitted from commercial airplanes through the Aircraft Meteorological Data Relay (AMDAR) system have also been incorporated into upper air observation, primarily in numerical models. Increasingly, data from weather satellites are being used because of their almost global coverage[10]. However, through the usage of this technique, little information can be used for numerical weather prediction (NWP) models, unlike polar orbiting and geostationary satellites both of which provide soundings of temperature and moisture throughout the depth of the atmosphere. Therefore, infrared (IR) data can be used as it gives information on the temperature at the surface and cloud tops. But compared with similar data from radiosondes, satellite data has the advantage of global coverage. Meteorological radar provides information on precipitation location and intensity, which can be used to estimate precipitation accumulations over time. Additionally, if a Pulse Doppler weather radar is used, wind speed and direction can be determined. Therefore, one of the future programmes of the IMD is enhancement of radar network and assimilation of radar data in NWP models because of the utility of this technique in Nowcasting. Also, the IMD modernisation programme includes replacement of all the radars with Doppler Weather Radars in a phased manner. Doppler Weather Radars will also be installed at some new locations to fill data gaps. However, there is a limitation to the use of radar since it can be used to find the location of the cyclonic storm more accurately when the system comes within its range. On the east coast a network of Cyclone Detection Radars (CDRs) has been established at Kolkata, Paradip, Visakhapatnam, Machilipatnam, Chennai and Karaikal, while on the west coast the network has been established at Goa, Kochi, Mumbai and Bhuj.

The conventional observations are supplemented by observational data from AWS using different techniques like radar and satellite systems[11] for forecasting. Satellite imagery is obtained at hourly intervals during cyclone situations. The accuracy of cyclone forecasts is comparable to corresponding figures for other centres like the National Hurricane Centre, Miami which monitors Atlantic hurricanes and the Typhoon Warning centre, Tokyo which monitors the north-west Pacific. With the development of new observing systems and new generation satellites, the accuracy is likely to increase further.

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[10] Meteorogical satellites of special relevance to TC analysis at IMD are INSAT and Kalpana, DMSP, NOAA, METEOSAT and TRMM.

[11] Before the early 1900s, though, most forecasts were done by direct observations at weather stations, which were then relayed to forecast centres via telegraph. It was not until the advent of radio in the early twentieth century that observations from ships at sea were available to forecasters. The 1930s saw the use of radiosondes in tropical cyclone forecasting. The next decade saw the advent of aircraft-based reconnaissance by the military, starting with the first dedicated flight into a hurricane in 1943, and the establishment of the Hurricane Hunters in 1944. In the 1950s, coastal weather radars began to be used in the United States, and research reconnaissance flights by the precursor of the Hurricane Research Division began in 1954. The launch of the first weather satellite, TIROS-I, in 1960 introduced new forecasting techniques that remain important to tropical cyclone forecasting to the present.

5.6 Dissemination of Cyclone Warnings

Warnings are issued to the general public, fishermen, farmers and different categories of users such as central and state government officials responsible for disaster mitigation and relief, industrial and other establishments located in the coastal areas, ports, coastal shipping, railways, aviation, transport, communication and power authorities. The state government takes the necessary steps to inform the local population through their machinery such as police wireless. All India Radio (AIR) broadcast is done 3-4 times daily in the local language. All information is shared with the press for wider dissemination. Other telecommunication channels used are telephone, telefax, Internet, websites, mobile phones, and Interactive Voice Response System[12] (IVRS). While disseminating the information, it should be taken into account that information about the latest position of the cyclone is passed in an effective manner to avoid the spread of rumours. People must be specially advised not to leave their shelter even if there is a lull in the wind/rain for it may be deceptive.

The satellite-based Cyclone Warning Dissemination System (CWDS) is a unique scheme not tried anywhere else in the world. It is capable of circumventing failure of the traditional communication systems. With the help of this system people are evacuated from low-lying areas and moved to temporary shelters before a cyclone strikes. The system is a direct broadcast of cyclone warning in regional languages to areas that are likely to be affected. There are 252 stations along the Indian coast which are equipped to receive the weather-related warning, of which 101 receivers using the latest digital techniques with a message acknowledgement facility were added in Andhra Pradesh. IMD's Area Cyclone Warning Centres (ACWCs) at Chennai, Mumbai and Kolkata are responsible for originating and transmitting the weather warning messages through CWDS. Through special CWDS receivers, the recipients can be selectively addressed and area-specific messages can be sent to the end-users. The CWDS receivers are kept on standby mode and get automatically activated on receipt of the weather warning messages. In case of a cyclone when all other means of communication fail, the CWDS continues working with battery back-up power via INSAT satellite.

Maps showing flood-inundated areas are prepared using data from Remote Sensing Satellites which are provided to various officials to help with relief and rescue operations. The remote sensing technology acquires data and information about objects or phenomena with the help of a device that is not in physical contact with it.

5.6.1 Warning Bulletins

Area Cyclone Warning Centres (ACWC) and Cyclone Warning Centres (CWC) issue the following bulletins and warnings:

- Sea Area Bulletin

[12] Popularly known as "Weather on telephone", the IVRS has been functioning from July, 2000. One can access current weather and forecast for major Indian cities by dialing the toll free number 1800 180 1717. This IVR facility has been installed at 26 meteorological centres. The system receives WMO formatted messages and decodes these messages to weather parameters (local warnings including multi-hazard warnings, maximum and minimum temperatures, rainfall, and local weather forecast). The system works with all types of exchanges used in DOT, MTNL, BSNL, etc. including mobile phones.

- Coastal Weather Bulletin
- Bulletins for the Indian Navy
- Fishery Warnings
- Port Warnings
- Aviation Warnings
- Bulletins for Department Exchanges
- Bulletins For A.I.R./ Doordarshan/ Press
- Cyclone Warning Dissemination System Bulletins
- Warnings for Registered/ Designated Users.
- Four-Stage Cyclone Warnings

5.6.2 Stages of Cyclone Warnings

The four stages of cyclone warning are;

1. Pre-cyclone watch. Issued to the Cabinet Secretary and senior officials indicating formation of a cyclonic disturbance which has the potential to intensify into a tropical cyclone and to affect the coastal belt.
2. Cyclone Alert. Issued at least 48 hours in advance, indicating expected adverse weather conditions.
3. Cyclone warning. Issued at least 24 hours in advance, indicating the latest position of the tropical cyclone, intensity, time and point of landfall, storm surge height, types of damage expected and actions suggested.
4. Post-Landfall Outlook. Issued about 12 hours before landfall and till cyclone force winds prevail. District Collectors of interior districts besides the coastal areas are also informed of the outlook.

Finally a 'De-Warning' message is issued when the tropical cyclone weakens into the depression stage. The cyclone warning is also disseminated to the following officials (Secretaries, Director General, etc.) along with the general public:

- Control Room of the National Disaster Management and Ministry of Home Affairs
- Cabinet Secretary
- Principal Secretary to the Prime Minister
- Ministry of Earth Sciences
- Department of Science and Technology
- Shipping and Surface Transport

Secretaries in the Ministries of

- Home Affairs
- Defence
- Agriculture
- Information and Broadcasting

Director General of

- Shipping
- Doordarshan
- All India Radio
- Head Quarter
- Integrated Defence Staff
- Central Relief Commissioner

5.7 Response and Actions needed during the Event

5.7.1 District Collector

The District Collector should establish contact with all subordinate officers at the subdivision, taluka, block and panchayat levels through police W/T and other available communication channels to apprise them of the impending cyclone. He should keep continuous track of the cyclone bulletins received from the Cyclone Warning Centre. Frequent personal contacts with the officer in charge of the Cyclone Warning Centres are recommended.

5.7.2 Local Committee

Departments like the police, fire brigade, PWD, irrigation, health, fishery, electricity boards, ports, railways and telecom services, organisations like the Red Cross and other NGOs engaged in disaster management and relief operations should meet at short notice to take stock of their preparedness to meet the cyclone threat. The help of voluntary organisations should be fully mobilised.

5.7.3 Public

People should be asked to remain calm and follow the instructions of the officials in charge of relief operations. Strongly built buildings located on high ground can be earmarked as shelters in advance.

5.7.4 Transport Authority

Surface transport organisations should be kept informed of the cyclone. Transport other than those required for emergency operations should be moved to a safer place. The service ability of the coastal railway line for movement of emergency supplies of essential commodities at short notice should be ensured.

5.7.5 Port and Fishery Officials

Areas where damage to country boats and fishing crafts is apprehended should be informed. Fishermen are to be alerted and they should be prevented from venturing into the open sea. Operations at ports may have to be suspended temporarily.

5.7.6 Health Officers

Emergency public health and sanitation services are to be set up under the supervision of the District Health Officer. Doctors/staff and hospitals should be alerted. First-aid centres should be set up at various locations along the coast with support from the local public and NGOs.

5.7.7 Relief Officers

Relief centres, emergency kitchens and feeding centres should be set up to provide food, drinking water and clothing to the affected people.

5.7.8 Co-ordination with Disaster Management Agencies

A contingency plan stipulating the triggering mechanism of the warning system and the responsibilities of various agencies in responding to natural disasters arising from the passage of tropical cyclones have been set up by the National Disaster Management (NDM) in India in all levels.

The effectiveness of a cyclone warning system is increased by enhancing the co-ordination among the IMD, government departments and non-government agencies to trigger rapid response actions. Regular liaison meetings between the IMD and key government departments or associated sectors such as transport operators are essential. A telephone consultation service by IMD with the key emergency response units during the threat is also relevant.

Box 3: Case Study - Nargis (May 3, 2008)

Nargis was the eighth deadliest cyclone of all times and the worst natural disaster in Burmese history. Nargis developed on April 27 in the central area of the Bay of Bengal about 1,150 km east-southeast of Chennai when it was detected by the IMD. As a result, on April 28 the IMD upgraded the system to Cyclonic Storm Nargis while it was located about 550 km east of Chennai. However, initially the cyclone was forecast to strike Bangladesh and Southeast India. On May 1, the storm changed its path and started turning eastwards towards Burma and intensified from Category 1 to Category 4 in just 24 hours. The Indian authorities warned Burma about the danger that cyclone Nargis posed 48 hours before it hit them[13]. However, the military junta[14] in Burma ignored the warnings and failed to warn the population. 'Heavy rain expected' was all that the state-owned media reported on May 2. In India, the India Meteorological Department (IMD) warned fishermen against sailing in the ocean during the passage of Nargis[15]. Also in Bangladesh, the farmers were asked to hurriedly finish harvesting the crop since strong winds could destroy the crop[16].

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[13] The World Meteorological Organisation (WMO) was established in 1972 with the objective of assisting the member countries to increase their capabilities to detect and forecast the approach of tropical cyclones and develop schemes to organise and execute disaster prevention and preparedness measures. As has been mentioned earlier a Regional Specialized Meteorological Centre (RSMS) has been established at IMD, New Delhi. IMD is one of six such centres recognised by the WMO under a global system for monitoring tropical cyclones. Tropical cyclone advisories are issued by the IMD in case of a cyclonic threat in the northern Indian Ocean to other panel member countries which are Thailand, Myanmar, Bangladesh, Pakistan, Maldives and Oman.

[14] Military dictatorship is the present form of government in Burma. Democratic rule was replaced by military rule in 1962.

[15] Crucial weather parameters which are looked at by IMD in case of a cyclone are wind speed and direction, pressure distribution, vorticity at 850hpa and wind shear. Also the frequency of the forecast issued increases with the intensity of the storm— 2 times a day for low pressure area, 5 times a day for depression or deep depression, and 8 times a day for cyclonic storm.

[16] As has been mentioned earlier other users of the IMD services apart from the WMO panel member countries are disaster management units of states that are likely to be affected, the Ministry of Home Affairs (MHA), all Secretaries and Chief Secretaries, the media, the Chief of Defence staff, naval command and Indian coast guards.

Impact of Cyclone Nargis
Reports estimated that more than 200,000 people were found dead or missing, and damage totalled US$ 10 billion from this cyclone. The World Food Programme reported, "Some villages have been almost totally eradicated and vast rice-growing areas are wiped out." Since the cyclone had hit right around the harvest season, local food prices increased, leading to widespread starvation in the country. Also, the government made no efforts to provide subsidised rice to the local population. The United Nations projects that as many as 1 million were left homeless and the World Health Organization "has received reports of malaria outbreaks in the worst-affected area."

Box 4: Case Study - AILA (May23, 2009 at 0600 UTC)

AILA crossed the West Bengal coast near Sagar Island and caused the loss of about 100 human lives and left several injured in West Bengal. In Bangladesh it caused 175 deaths and injured several people.

Special Features of AILA
(i)The system moved in a near-northerly direction throughout its span
(ii) It intensified into a severe cyclonic storm only a few hours before landfall
(iii) The system maintained the intensity of the cyclone (T2.5) even up to 15 hours after landfall.

Genesis
The southwest monsoon set in over the Andaman Sea and the adjoining south Bay of Bengal on 20th May 2009. The southerly surge over the region increased, resulting in the horizontal pressure gradient and north-south wind gradient over the region. Hence, the lower level horizontal convergence and relative vortices[17] increased gradually over southeast Bay of Bengal.

Intensification and Movement
The depression mainly moved in a northerly direction and intensified into a deep depression and lay centred at 0300 UTC on 24th May near Latitude 18.0^0 N/ Long 88.5^0 E. It continued to move in a northerly direction and intensified into a severe cyclonic storm over northwest Bay of Bengal close to Sagar Island.

Impact of AILA
Heavy Rainfall. Widespread rain/thundershowers with scattered heavy to very heavy rainfall and isolated extremely heavy rainfall (>25 cm) occurred over Orissa on 25th May, and over West Bengal and Sikkim on 25th and 26th May. On 26th and 27th May heavy to very heavy rainfall occurred over Assam and Meghalaya.

Strong Winds. The sustained maximum wind at the time of landfall was about 60 knots (112 kmph).The wind speed reported by different station like Kolkata, Panagarh, Kalaikunda, Barrackpore, Kakdwip, and Sagar Island varied between 75 and 112 kmph..

Storm surge. A storm surge of 3 metres impacted the western region of Bangladesh, submerging numerous villages. The Sunderbans was inundated with 6 metres of water as per media reports.

Losses in West Bengal
Number of storm-affected people – 2.2 million; number of people died- 100
Houses collapsed – 61,000; houses partially damaged- 132,000;

The cyclone caused extensive damage to rice and other crops. The Sunderbans mangrove forest area, home to the highly endangered Royal Bengal tiger, was completely inundated. High-speed winds destroyed all communication and transportation infrastructure. The entire Sunderbans biosphere reserve area of 9,600 square kilometres suffered extensive damage. AILA affected sub-Himalayan West Bengal and Sikkim, uprooting trees and causing landslides and floods.

Losses in Orissa
The heaviest rainfall was recorded at Paradip (260 mm) and winds peaked at 90 km/hr. Numerous trees were uprooted. High waves inundated coastal villages, forcing the residents to evacuate to safer areas. However, there was no report of human deaths in the state. An estimated 1,000 acres of cropland were affected.

Losses in Meghalaya
AILA produced gusty winds and heavy rains in Meghalaya between May 25 and 26. Rainfall peaked at 213.4 mm and winds reached 60 km/h. No injuries were reported in the state. Several homes were damaged and power was cut off due to fallen trees and power lines. Several streets were flooded and some homes were reported to have standing water.

[17] The motion of the fluid swirling rapidly around a centre is called a vortex.

Box 5: Case Study - LAILA (17th May 2010 at 0600 hours)

A severe cyclone storm crossed south coastal Andhra Pradesh and affected districts like Guntur, Prakasham and Krishna. Some of the mandals of Guntur districts which were badly affected were Bapatla, Repalle, Nizampatnam and Karlapalem. Badly affected places from Prakasam districts were Addanki, Chirala and Kothapatnam.

Genesis

A low pressure area over southeast Bay of Bengal and its neighbourhood concentrated into a depression near latitude 10.5^0 North and 88.5^0 East about 1,000 kms southeast of Vishakhapatnam.

Intensification and Movement

It moved northeast and intensified into a deep depression as it moved southwest and into the adjoining southeast and west central Bay of Bengal. Finally it moved northwards, close to Bapatla, and crossed the coast between 20/1100 UTC and 20/1200 UTC near Bapatla over land, and then weakened gradually. The landfall point of LAILA was about 15.8N/80.6E at Suryalanka coast, which is located about 12 kilometres south-southeast Bapatla. It is assumed that the system might have taken a diversion near Karlapalem village and Satyavathipeta. During its course of re-curvature, it was lying stationary at that village for four to five hours and later it took a diversion in an east-northeasterly direction. The strongest winds were found on the right side of the storm. The storm was moving initially at the landfall position in a north-northwesterly direction. Hence, the right side of the storm was towards the east of the storm. It is due to this fact that the system contributed to its swirling winds. Due to convergence and spiralling of winds from the northwest and westerly directions, the winds were strong in the southwest sector of the system. For the same reason, Ongole district, which located exactly on the southwest sector of the system, received copious rainfall. In particular, the highest rainfall of 61 cms was recorded over Kothapatnam and Addanki mandals of Ongole district. It was assumed that the system might have attained the Severe Cyclonic Storm Stage while crossing the coast and then gradually weakened into a Cyclonic Storm Depression.

Impact

Wind speed: During the cyclone, the maximum wind speed observed by Suryalanka Air Force Station was 53 knots (98 kmph). As per the local people and fishermen, wind speed at Vadarevu (Prakasam district), Suryalanka and Nizampatnam of Guntur districts, the wind speed was 125-150 kmph at the time of land fall.
Tidal waves: IMD forecast that the sea waves would reach a height of 9-14 mts. As observed by the fishermen in Vadarevu, the waves were within 6 mts. At Suryalanka and Kothapatnam the height was within 5-6 mts.
Storm Surge: The observed storm surge was much higher than the forecasted one. In Suryalanka the storm surge was between 2-3 metres and in Vadarevu it was within 3-4 metres.

Losses in Ongole District

Heavy rains and gales caused floods in all the mandals of Ongole district. A record rainfall of 522.2 mm was received in Addanki Mandal, which was highest in the state during 24 hours. The cyclone affected 293 villages in 26 mandals covering 1.62 lakh of population. 7 casualties were recorded. 2,836 houses were completely damaged, 6,803 houses were severely damaged and 22,563 houses were inundated. 210.71 kms of road surface was damaged. Huge losses occurred in tobacco, horticulture, animal husbandry, fishery, handlooms and textiles. As per the preliminary assessment, 497.72 crore of total loss occurred. The loss to the public sector was estimated at ₹ 413.43 crore and in agriculture and allied sectors the loss stood at ₹ 84.29 crore. The estimated loss in roads and buildings was 63.75 crore.

Losses in Guntur District

In Guntur district 5 mandals, 53 villages and 2 towns were affected, with total geographical area of 649.79 sq.km. The number of people affected by the cyclone was more than 43,000.

The cyclone killed 6 people and 295 animals. 67 roads, 20 drains and 8 culverts were damaged. More than 300 houses were completely damaged and 523 houses were damaged partially. A number of banana and papaya trees, and betel vines were uprooted.

Relief Measures
In Ongole district, 800 labourers were drafted for cleaning the sanitation, removing the fallen trees and clearing the traffic obstructions. 30 tankers were utilised to transport drinking water to all marooned *bastis* and other areas. Moe than 2 lakh food packets and more than 7 lakh water sachets were distributed in relief camps. Milk and bread were also supplied to children. Medical camps were organised. Various sanitation measures like bleaching, lime and phenol application and sprinkling of crude oil on water bodies were taken up in affected villages. 19 teams were appointed to enumerate of house damages and to disburse financial assistance to fully and severely inundated households. Fully damaged households got cash of ₹ 5,000 and ₹ 3,000 for clothes and utensils.

In Guntur district 55,000 food packets and more than 95,000 water sachets were distributed. 3 boats were deployed to carry out the relief work. Relief measures were given to almost all the households damaged in the cyclone. The total expenditure on relief measures amounted to more than ₹ 4 crore.

Recommendations
All stations should be provided with UPS systems with long battery back-up. Supplies of group cell phones are also very useful for better communication.

All government officials, mandal head quarters, and district collectorates should maintain the status of the station with longitude and latitudes and their district maps and mandal maps to be kept ready.
IMD can depute a person on tour to all coastal districts of Andhra Pradesh by providing a GPRS system to get the latitude and longitudes of all mandals of the coastal districts and to prepare a map of coastal Andhra Pradesh according to the scale and position for future use in post-cyclone surveys.

While the touring party is proceeding for surveys, the concerned locals in charges of observatories in the affected areas are to be instructed to participate and their names should be proposed for local assistance.

Cyclones cause more damage than the faster and wider-reaching typhoons and hurricanes. Overall, the Indian sub-continent generates 7 percent of the globe's tropical cyclones and records the highest number of human deaths from them. The populous and poorer Asian coast struggles with poor warning systems that give little advance warning.

In this segment, a total of 200 persons from the general population were covered across the two states of Andhra Pradesh and West Bengal. The districts covered include Baptala in Andhra Pradesh, and Kalyani and 24 Paraganas in West Bengal.

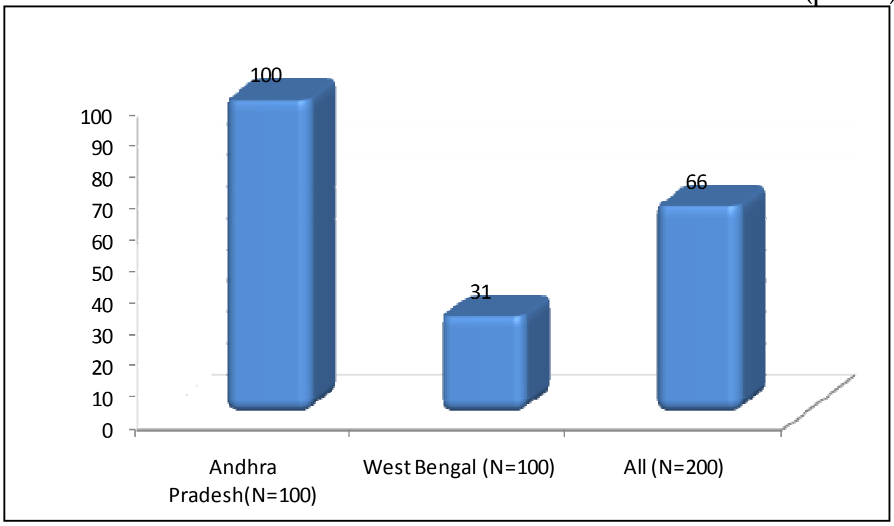
5.8 Awareness and Sources of Cyclone Warning Services

This section presents the findings pertaining to awareness among heads of households (general population) on cyclone warning services and sources of cyclone warnings.

5.8.1 Awareness of Early Cyclone Warning Services

All the heads of households were asked whether they are aware of early cyclone warning services. Two-third (66%) of them are aware of such services. In Andhra Pradesh all heads of households are aware of cyclone warning services, while in West Bengal less than one-third (31%) are aware.

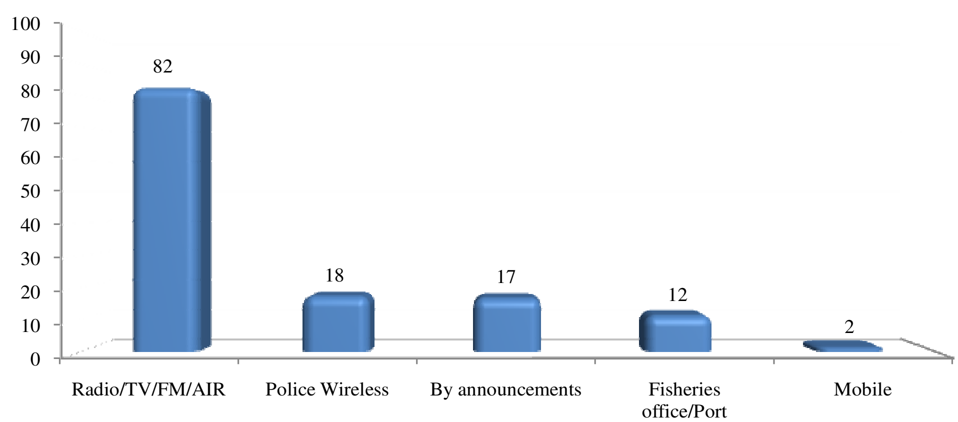
Figure 5.1: Adult Males and Females Aware of Early Cyclone Warning Services
(percent)



5.8.2 Sources of Information on Early Cyclone Warning

Those heads of households who reported being aware of early cyclone warning services were asked about the sources from where they receive such information. Figure 5.2 indicates that radio/TV/FM/AIR are the major sources of information as they were reported by more than four-fifth (82%) of the adults. Nearly one-fifth reported police wireless (18%) and public announcements (17%) as the source of information. The fishery office/port and mobiles are other sources which provide early information on cyclones.

Figure 5.2: Sources of Information on Early Cyclone Warning Services
(percent)



Awareness of and access to cyclone-related web pages or bulletins is substantially low in the target population.

5.9 Utilisation and Appropriateness of Early Cyclone Warning Services

5.9.1 Appropriateness of Language and Timing of Cyclone Warning Messages

The present study attempted to find out the quality of information provided under the early warning services. In this regard the heads of households were asked about the appropriateness of message/information in terms of timing and language. The majority reported that language and timing is appropriate and they also felt that the message was simple, relevant and concise (Figures 5.3 and 5.4).

Figure 5.3: Weather Message Appropriacy in Terms of Language and Timing

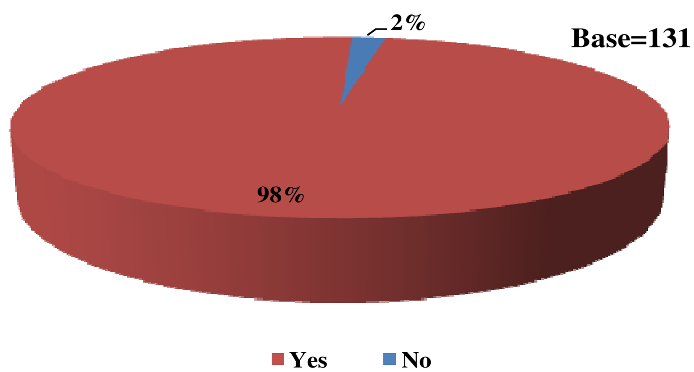
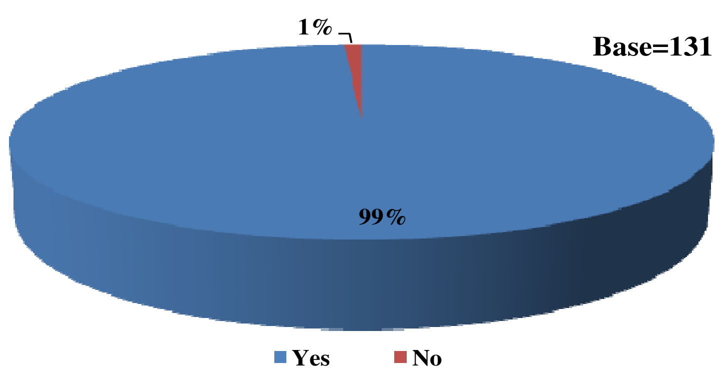


Figure 5.4: Whether Weather Message is Simple, Relevant and Concise

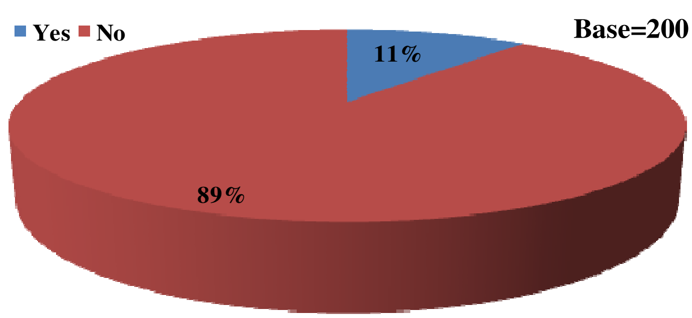


5.9.2 Willingness to Pay for more Specific Information

Heads of households were asked if they would be willing to pay to receive more specific information on cyclone warnings. Figure 5.5 reveals that the majority (89%) are not willing to pay, perhaps because of today's active media and the strong and effective initiatives taken by the government before a cyclone. If the information which is received free of cost is authentic, quick and exhaustive, there is no point in paying for the same.

Half of those heads of households who are not willing to pay stated that they have economic problems, whereas nearly one-fifth reported that they get information through TV.

Figure 5.5: Willingness to Pay for Weather Information



5.9.3 Reliability of Information

Those heads of households who reported receiving cyclone alerts and warning messages were asked about the reliability of information for different areas of information irrespective of the source of information (Table 5.3). Almost all the heads of households covered in this segment feel that the information they receive is reliable.

Table 5.3: Reliability of Information

Areas of Information	Number of heads of households received information	Percent stated that the information is reliable
Strong off-shore and on-shore winds	106	97.2
Frequent rain squalls	74	98.6
Persistent gusty winds accompanied by rain	116	99.1
Gales	104	98.1
State of sea	23	95.7
Direction of movement and speed of the wind	10	100.0
Probable affected area	23	100.0
Heights of tidal waves	99	99.0
Area Likely to be affected by heavy rainfall which may cause floods	25	96.0
Areas of the coast affected by waves	89	95.5
Storm surge	105	100.0
Total N		**131**

5.9.4 Use of Early Warning Information

Table 5.4 presents the findings on use of information to save or minimise loss. This particular question was asked to assess the utility of the information in terms of money. More than half the heads of households reported that the early warning information on cyclones helps in saving their food stock (60%), utensils (54%) and livestock (49%). The state-wise analysis reveals that the population from Andhra Pradesh utilise the early warning information in a more effective manner to save or minimise loss than the population from West Bengal.

Table 5.4: Use of Early Warning Information to Save or Minimise Loss

(percent)

	Andhra Pradesh	West Bengal	All
Food stock	99.0	21.0	60.0
Utensils	100.0	8.0	54.0
Livestock	89.0	8.0	48.5
House	70.0	5.0	37.5
Well and water storage	57.0	0.0	28.5
Durables	46.0	0.0	23.0
Fuel	11.0	13.0	12.0
Water pump	8.0	1.0	4.5
No response	0.0	4.0	2.0
Total N	**100**	**100**	**200**

Note: Total exceeds 100 due to multiple responses

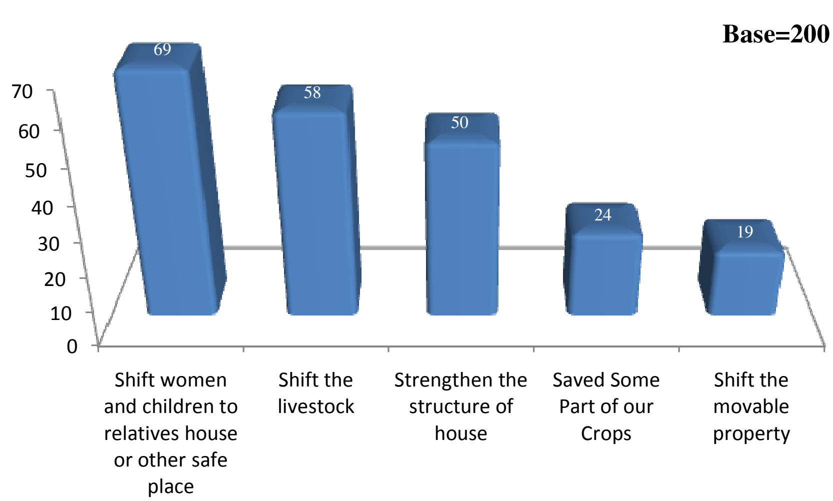
5.10 Preparedness and Experience of Last Cyclone

This section presents the findings on preparedness to face cyclones and experiences of the last cyclone.

5.10.1 Preparedness for Cyclones

Figure 5.6 describes different steps taken as preparedness before a cyclone. The analysis suggests that shifting women and children to relatives' house or other safe places (69%), shifting livestock (59%), strengthening the structure of the house (50%) and shifting movable property (19%) are the top four steps taken as part of preparedness.

Figure 5.6: Preparations before Cyclone (percent)



5.10.2 Coping and Adaptive Strategies during Cyclone

Coping Strategies

Heads of households were asked about coping strategies adopted during the previous cyclone. Table 5.5 reveals that two-third (66%) took assistance from relatives for accommodation and relief, while nearly one-fourth (22%) engaged in farming on a sharing basis (shared cropping) with others. A few other heads of households also reported using common property resources like the nearby forest area (12%) and selling assets like land, livestock, etc. (6%) as a coping strategy during/ after the cyclone.

Table 5.5: Coping Strategies Adopted during/after Cyclone

(percent)

Strategy	Andhra Pradesh	West Bengal	All
Assistance from relatives for accommodation and relief	83	48	65.5
Share cropping	33	11	22
Using common property resources like nearby forest area	10	14	12
Selling assets like land, livestock, etc.	6	6	6
Total N	**100**	**100**	**200**

Adaptive Strategies

Table 5.6 depicts the adaptive strategies adopted during the cyclone. About three-fifth (57%) of the heads of households from West Bengal reported that they migrated, whereas in Andhra Pradesh about two-fifth (38%) reported to have stayed at their home and another 28% had taken up other occupations such as laundry, domestic help, construction work, and driving.

Table 5.6: Adaptive Strategies during/after Cyclone

(percent)

Strategy	Andhra Pradesh	West Bengal	All
Migration	8.0	57.0	32.5
Taking up subsidiary work: laundry, domestic help, construction work, driving, etc.	28.0	6.0	17.0
Shifting from light materials to more durable materials in house construction	7.0	11.0	9.0
Stay at home	37.9	6.0	21.9
No response	15.0	19.0	17.0
Total N	**100**	**100**	**200**

5.10.3 Experiences during previous Cyclone

Heads of households were asked to share their experiences about post-cyclone mitigation measures adopted during the previous cyclone.

Table 5.7 reveals that free supply of food and drinking water (58%), free medicines (54%), free health check-ups (53%) and spraying of insecticides (33%) are the top four mitigation measures adopted during the last cyclone. In Andhra Pradesh, the majority of heads of households reported these as the top mitigation measures, whereas in West Bengal very few reported so.

Table 5.7: Cyclone Mitigation Measures Adopted during Previous Cyclone

(percent)

	Andhra Pradesh	West Bengal	All
Free supply of food and drinking water	85.0	30.0	57.5
Supply of medicines	99.0	9.0	54.0
Free health check-up	98.0	7.0	52.5
Spraying of insecticides	63.0	2.0	32.5
Assessment of loss/damage	32.0	6.0	19.0
Special care to children and aged	15.0	0.0	7.5
Cash payment	10.0	3.0	6.5
Distribution of consumer items	8.0	5.0	6.5
No response	0.0	10.0	5.0
Total N	**100**	**100**	**200**

CHAPTER VI
Tsunami Early Warning System

A tsunami is a wave train, or a series of waves, generated in a body of water by an impulsive disturbance that vertically displaces the water column. It is a Japanese word which means "harbour wave". It is generated when the sea floor abruptly deforms and vertically displaces the overlying water. When tectonic earthquakes[18] of a magnitude of more than 7 on the Richter Scale occur beneath the sea, water above the deformed area is displaced from its equilibrium position and generates a tsunami. Other factors like volcanic eruption and landslides can also generate a tsunami.

Tsunamis not only propagate at high speeds, but they can also travel great, trans-oceanic distances with limited energy losses. The speed of a tsunami wave is related to the water depth. It generally passes unnoticed at sea, forming only a slight swell with a small wave height offshore, and a very long wavelength (often hundreds of kilometres long).They grow in height when they reach shallower water. Because of this shoaling effect, the wave gets compressed and its velocity declines. Its wavelength diminishes and its amplitude grows enormously, producing a distinctly visible wave. A tsunami which was imperceptible at sea grows to several metres near the coast, forming large destructive waves.

There are three stages in a tsunami: generation, propagation, and run-up (inundation).

The *generation* stage of tsunami evolution includes the formation of an initial disturbance at the ocean surface due to the earthquake-triggered deformation at the sea floor. This initial water surface disturbance is transformed into a long gravity wave radiating from the earthquake source. Tsunamis travel outward in all directions from the generating area, with the direction of the main energy *propagation*. Generally it is orthogonal[19] to the direction of the earthquake fracture. Their speed depends on the depth of the water, so that the waves undergo acceleration and deceleration in passing over an ocean bottom of varying depth. In the deep and open ocean, they travel at speeds of up to 100 to 500 km/hr.

When the tsunami's wave peak reaches the shore, the resulting temporary rise in sea level is termed *run-up*. Run-up is measured in metres above a reference sea level. A large tsunami may feature multiple waves arriving over a period of hours, with significant time between the wave crests. The first wave to reach the shore may not have the highest run-up.

6.1 The National Tsunami Early Warning System

Recognising the threat to the life and property of the coastal population and further as a national calamity due to the Indian Ocean tsunami of December 26, 2004 the Ministry of Earth Sciences

[18] A tectonic earthquake is an earthquake where two tectonic plates rub against each other and then scrap because the jagged edges cause vibrations which are realised as an earthquake. It is associated with the earth's crustal deformation.
[19] At right angles or perpendicular.

(MoES) as the nodal ministry established the National Tsunami Early Warning System. An Interim National Tsunami Early Warning Centre set up at INCOIS, Hyderabad has been operational since October 15, 2007.

In the Indian Ocean there are two tsunamigenic zones

1. Andaman-Sunda-Sumatra Island Arc in the Bay of Bengal
2. Makran Subduction Zone in the Arabian Sea

The Interim Tsunami Warning Centre follows a Standard Operational Procedure (SOP) which receives earthquake information from national and international sources. It also gets a tsunami warning from the Japan Meteorological Agency (JMA) and the Pacific Tsunami Warning Centre (PTWC). The INCOIS Centre issues earthquake information and a tsunami bulletin whenever an earthquake of magnitude of >6.5 has occurred in the Indian Ocean to the Ministry of Home Affairs (MHA) within 30 minutes. This is followed by an upgrade message or a cancellation message within 60 minutes based on water-level information from the National Institute of Ocean Technology (NIOT).

Preliminary Assessment of Tsunamigenic Potential

$7.0<M<7.5$ Possibility of local tsunami

$7.5<M<8.0$ Possibility of regional tsunami

$M>8.0$ Possibility of an ocean-wide tsunami

The Indian Tsunami Early Warning System comprises a real-time network of seismic stations, Bottom Pressure Recorders (BPRs), tide gauges and a 24x7 operational tsunami warning centre to detect tsunamigenic earthquakes, monitor tsunamis and provide timely advisories to vulnerable communities by means of the latest communication methods with the back-end support of a scenario database, vulnerability modelling and Decision Support System.

6.2 Components of the Indian Tsunami Early Warning System

- A dedicated Tsunami Warning Centre operating on a 24x7 basis for generation of timely advisories
- A network of land-based seismic stations for earthquake detection and estimation of focal parameters in the two known tsunamigenic zones and to communicate the same to the Early Warning Centre in near real time
- A network of 12 bottom pressure recorders (that can detect and measure a 1 cm change in the water level at water depths of up to 6 km of water) to detect and monitor tsunamis around these two tsunamigenic zones
- Real-time observational network for upper-ocean parameters and surface met-ocean parameters, especially in the area of cyclogenesis and coastal sea, to improve the forecasting of storm surges
- A network of 50 real-time tide gauges, radar-based coastal monitoring stations and current meter moorings to monitor the progress of tsunamis and storm surges

- Generation of a high-resolution database on bathymetry, coastal topography, coastal use (for coastal areas within 1-3 km in general and for 10-25 km at selected areas near coastal water bodies).
- Coastal vulnerability modelling and inundation mapping
- Capacity building, training and education of all stakeholders on utilisation of the maps, warnings and watch advisories.

One of the most critical aspects of the tsunami warning system is to estimate earthquake parameters with reasonable accuracy in the shortest possible time. As part of the Indian Tsunami Early Warning System, a Real-Time Seismic Monitoring Network (RTSMN) has been established by the Indian Meteorological Department (IMD) to monitor and report accurately the occurrence of tsunamigenic earthquakes in the two probable source regions in the Indian Ocean within the least possible time. INCOIS also receives data from 10 seismic stations from the Wadia Institute of Himalayan Geology (WIHG). In addition to the Indian network, co-ordinated international networks like IRIS, GSN, and GEOFON via the Internet also provide seismic data to INCOIS.

6.3 History of Occurrence of Tsunamis in India

On December 26, 2004 the massive tsunamigenic earthquake of magnitude 9.3 in the Indonesian region devastated many parts of the Tamil Nadu coast, including other coastal areas of the Indian Ocean. From the available evidence it has been asserted and reported that 80% of the tsunamis in the Indian Ocean are from the Sundra Arc region (Table 6.1).

Table 6.1: Tsunamis that Affected the Indian Coast prior to the Sumatra Earthquake of December 26, 2004

Date	Cause	Impact
12th April, 1762	Earthquake in the Bay of Bengal	Tsunami wave of 1.8 m at Bangladesh coast
31st December, 1881	Earthquake of magnitude 7.8 beneath the Car Nicobar	Entire east coast of India, including Andaman and Nicobar coast, was affected
27th August, 1883	Eruption of Krakatau Volcano (Sunda Straits), Indonesia	East coast of India was affected and 2 m tsunami was reported at Chennai
26th June, 1941	Earthquake of magnitude 8.1 in Andaman	East coast of India was affected by tsunami
27th November, 1945	Earthquake of magnitude 8.1 in the Makran subduction zone (Baluchistan, Pakistan)	West coast of India was affected by tsunami

6.4 Performance Record of Indian Tsunami Early Warning System

The performance Statistics of Tsunamigenic earthquake in the Indian Ocean reported eight earthquakes from August 10, 2009 to June 12, 2010 with a magnitude of more than 6.9 Mwp. Tsunami evaluations by INCOIS of these earthquakes indicated the absence of any threat to the Indian region. In the earthquake of June 12, 2010, a tsunami watch based on model simulations was issued for North Nicobar Island. But after confirming that there were no significant changes in real-time water level observations, the watch was cancelled.

6.4.1 Bottom Pressure Recorders (BPR)

Not all earthquakes trigger tsunamis. For confirmation, it is essential to measure the change in water level in the open ocean with high accuracy in real time. Bottom Pressure Recorders (BPRs) are used to detect sea level changes near tsunamigenic source regions and the consequent propagation of tsunami waves in the open ocean.

6.4.2 Tide Gauges

To monitor the progress of a tsunami and later for cancellation of the warning, it is essential to monitor the coastal sea-level changes. This calls for a network of real-time tide gauges installed in strategic locations. Such a network of tide gauges may be the only way to detect a tsunami in cases where seismic data is not available or when the tsunami is triggered by events other than an earthquake. A real-time network of tide gauges has been established by the Survey of India (SOI) and the National Institute of Ocean Technology (NIOT). The network is designed to measure and monitor the progress of tsunamis from the two tsunamigenic source regions of the Indian Ocean in real time. In addition to the Indian tide gauge network, real-time tide data is received by INCOIS from the Global Sea Level Observing System (GLOSS) in the Indian Ocean.

6.4.3 Tsunami Modelling

Model scenarios are being generated for all possible earthquakes and for issuing a warning/ watch/advisory to different coastal locations and for grading tsunamis. This would ensure the control of false alarms. Different coastal regions have their own criteria based on their proximity to earthquake zones. For example, an earthquake occurring in the Sumatra subduction zone will have different criteria for generation of warnings for the Andaman and Nicobar Islands and for the mainland. Sufficiently accurate modelling techniques require proper inputs on detailed bathymetry and topographic data for the area being modelled. Most tsunami models apply different numerical techniques to different segments of the problem starting from tsunami generation, propagation and run-up on coastal areas. For example, several numerical models have been used to simulate the interaction of tsunamis with islands. These models have used finite difference, finite element and boundary integral methods to solve the linear long wave equations. These models solve these relatively simple equations and provide reasonable simulations of tsunamis for scientific and engineering purposes. In this study, a finite difference code of TUNAMI N2 was employed to study the tsunami.

INCOIS has conducted a study to validate the model results with the December 26, 2004 earthquake that indicated an 80% match. This model has been run for five historical earthquakes and the predicted inundation areas are being overlaid on cadastral level maps of 1:5000 scale. The maps for the most vulnerable parts of the coastline have been provided to central and state-level departments that are involved in disaster management.

6.5 Dissemination

The Early Warning Centre uses a custom-built software application that generates alarms/alerts in the warning centre whenever a pre-set threshold is crossed. Tsunami bulletins are then generated based on pre-set decision support rules and disseminated to the concerned authorities for action.

The advisory bulletin messages (Warning/ Alert/ Watch) are given for a particular region of the coast based on the earthquake parameters, available warning time (i.e., the time taken by the tsunami wave to reach a particular coast) and expected run-up from the pre-run model scenario.

Tsunami Bulletin Messages

Earthquake Information Bulletin. This contains information about origin time, latitude and longitude of the epicentre, name of the geographical area, and magnitude and depth of an earthquake. This message also contains preliminary evaluation of the tsunami potential based on the magnitude.

Table 6.2: Nature of Tsunami Messages, Advisories and Dissemination Sources

Message type	Nature of Tsunami and action	Dissemination to
WARNING	Major tsunami expected; move to higher ground	MoES, MHA, media, public
ALERT	Medium tsunami expected; strong currents; avoid beaches	MoES, MHA, media, public
WATCH	Minor tsunami expected; local authorities to be prepared	MoES, MHA,
ALL CLEAR	Tsunami threat passed	MoES, MHA, media, public

The triggering of a tsunami is confirmed with real-time observations if they show more than the threshold values. The 'Confirmed' Information Bulletin is generated with observed water levels. The identified coastal areas which are under 'Watch' status will be upgraded to either 'Warning' or 'Alert' status. If the observations do not show more than threshold, a 'Tsunami Cancellation Bulletin' is sent to the MoES, MHA and authorised people with the water-level observations.

A 'Confirmed Tsunami Information Bulletin' is sent to the MoES, MHA and local authorities after 30 minutes of the tsunami, as and when the real-time water level observations are available (not later than 60 minutes).

As per Standard Operational Procedures (SOP), the warning centre sends the

- Tsunami Warning Bulletin to the MoES, MHA and the public
- Tsunami Alert Bulletin to the MoES, MHA and the public
- Tsunami Watch Bulletin to the MoES, MHA.

If real time does not show any significant water level changes, all bulletins issued previously are cancelled by issuing a 'Cancellation' Bulletin.

In cases where a tsunami Warning/Alert/Watch is issued, the Warning Centre continues to monitor the tsunami activity through tide gauge water-level observations and other complementary observations. If observations indicate that the tsunami activity has decreased and no more damaging tsunami waves are expected, the Warning Centre updates the status and issues the tsunami 'All clear' bulletin to the respective coastal regions. If the earthquake is >6.5 M and <100 km depth, a warning has to be issued for areas falling within one hour travel time to avoid unnecessary evacuation as small earthquakes do not generate a tsunami. If the area is just within one-hour travel time and the earthquake is large, a watch is issued which is upgraded/downgraded based on water-level observations.

With world-class computational, communication and technical support facilities, the Indian Tsunami Warning Centre is capable of detecting tsunamis originating in the Indian Ocean. With the application of software based on geospatial technologies, it generates and disseminates timely tsunami advisories to the Indian Ocean countries. In future INCOIS is trying to begin a regional tsunami watch service for the Indian Ocean region with extended information services on potential tsunami threats and travel times, run-up height and potential threat zones. The centre can also support the generation of inundation maps and risk and hazard assessments. Bilateral and multilateral agreements are being negotiated with the Asian Disaster Preparedness Centre (ADPC), Maldives, Mauritius, Thailand, etc. for assistance in providing tsunami advisories.

Box 6: Case Study - Southern Sumatra Earthquake

Date and time. 12th September, 2007 at 16:40:26 (IST)
Near southern Sumatra in Indonesia two large earthquakes of about 8.4 magnitude occurred at a depth of 30.2 km. The earthquake was large enough to generate an ocean-wide destructive tsunami.

Dissemination
An alert was issued by the first Tsunami Information Bulletin from INCOIS for the Andaman and Nicobar Islands, which meant that 'No Evacuation' is required; however, the public needs to be vigilant. It was issued after 25 minutes of the event which was well within the stipulated Standard Operating Procedure.

The second bulletin issued at 18:28:00 continued the alert for the Andaman and Nicobar Islands as the water level at Padang (60 cm) and Cocos Island (50 cm) indicated a minor tsunami had been generated. Keeping in view the uncertainty of about 20% in the model estimates, the alert to the Andaman and Nicobar Islands was maintained. At 18:40:00 a directivity map indicated that the southeast Coast of India and the Andaman and Nicobar Islands may experience a minor tsunami. It was decided to downgrade the 'Alert' at the Andaman and Nicobar Islands to 'Watch' and issue a 'Watch' for the southeast and southwest coasts of India.

In the third tsunami information bulletin, an 'Alert' for the Andaman and Nicobar Islands and 'Watch' for Andhra Pradesh, Tamil Nadu and Kerala were issued at 19:35:00 hours. Finally, at 21:15:00 hours an 'All clear' bulletin was issued as the water levels showed minor variations.

The PTWC issued the first watch Bulletin at 17:00:00 with the information about an earthquake of magnitude 7.9m and was followed by the second Watch bulletin at 17:24:09 with the revised magnitude of 8.2M. The Japan Meteorological Agency (JMA) issued the first tsunami watch bulletin at 17:07:09 which was followed by the second Watch bulletin at 18:01:09 with the revised magnitude of an earthquake of 8.2M.

6.6 Performance of Sensors, Simulation Tools and Decision Support Systems

6.6.1 Earthquake

For the event of Sept 12, 2007 INCOIS got earthquake information from alternate sources such as the California Integrated Seismic Network (CISN), Geofon and the United States Geological Survey (USGS). Using Seiscomp software, real-time seismic data from 240 seismic stations (200-IRIS and 40 – GEOFON, GEOSCOPE) is received at INCOIS and auto-location is done within 10-15 minutes after an earthquake occurs. There is a limitation in the SEISCOMP 2.0 software which INCOIS is trying to overcome with SEISCOMP 3.0 designed for tsunami warning purposes which gives the estimates of the Megawatt Peak (Mwp) in addition to Mb[20] and *focal mechanism*[21].

The earthquake information from the IMD came at 17:55:09 which explains the delay of almost 55 minutes. The IMD is supposed to provide earthquake information within 20 minutes of the event. But this information was provided only after 75 minutes which could not be used in the decision making of tsunami bulletins.

6.6.2 Suggestions

The IMD should put immediate effort into installing 17 seismic stations as part of the Real-Time Seismic Monitoring Network (RTSMN) and configure the software required for real-time data reception, archival and auto location.

6.6.3 Bottom Pressure Recorders

Data from BPRs is critical for confirming the triggering of a tsunami. During the earthquake event on Sept 12, 2007, five Indian BPRs (TB-03,TB-10.TB10A andTB-7) and one NOAA BPR were functioning in the Indian Ocean. The data from all the BPRs were found to be of good quality. However there was a delay of about two hours in data reception of the BPs at INCOIS which led to a significant delay in issuing a confirmation about tsunami waves and issuing an 'All Clear' bulletin. The National Institute of Ocean Technology (NIOT) said that the delay in communication was probably due to the messages getting queued at the INMARSAT earth station at Singapore.

[20] Mb is measured using the first five seconds of a teleseismic (distant) P-wave and Ms is derived from the maximum amplitude of the Rayleigh wave. A Rayleigh wave rolls along the ground just like a wave rolls across a lake or an ocean. Rayleigh waves are a type of surface acoustic wave that travels on solids. They are produced on the Earth by earthquakes, in which case they are also known as "ground roll". It is named after John William Strutt, Lord Rayleigh, who mathematically predicted the existence of this kind of wave in 1885.

[21] The *focal mechanism* of an earthquake describes the inelastic deformation in the source region that generates the seismic waves. Seismologists refer to the direction of slip in an earthquake and the orientation of the fault on which it occurs as the focal mechanism. They use information from seismograms to calculate the focal mechanism and typically display it on maps as a "beach ball" symbol. This symbol is the projection on a horizontal plane of the lower half of an imaginary, spherical shell (focal sphere) surrounding the earthquake source.

6.6.4 Tide Gauges

Data from tide gauges help to confirm and monitor the progress of tsunamis. In the event, data from four international stations (Padang, Cocos Island, Cilicap, and Colombo) and 2 SOI stations (Port Blair and Chennai) were found to be useful. Tidal data from the international tide stations (Padang and Cocos islands) were available with a delay of 15 minutes which confirmed the triggering of a minor tsunami. The data from international tide stations are very useful for earthquakes occurring near the Java-Sumatra seduction Zone.

Data from NIOT tide gauges was not useful due to their poor quality and large communication delays. NIOT accepted the delay for GSM (Global System for Mobile) communication which is currently used by the tide gauges.

6.6.5 Simulation Tools

INCOIS generated a database of model scenarios considering various earthquake parameters. For the September 12, 2007 event the closed scenario IDs 28.2 and 29.2 were picked from the scenario database. They were used to calculate the estimated travel time and run-up heights at various coastal locations and water level sensors (tide gauges and BPRs). The estimates from the model scenario matched very well with the observations from BPRs and tidal stations.

Box 7: Case Study - Northern Sumatra Earthquake

Date and time- 6th April 2010 at 22:15:03 (UTC)[22;] 7th April 2010 03:45:03 (IST)
An earthquake of magnitude 7.7 occurred in the Nias[23] region of northern Sumatra at 03:45:03 (IST) on on 6th April 2010 at 22:15:03 (UTC) or 7th April 2010

The Tsunami Warning Centre located this earthquake 4 minutes after it occurred. The earthquake occurred as the result of thrust faulting on or near the subduction interface plate boundary between Australia-India and the Sunda plates. At the location of this earthquake, the Australia and India plates move north-nort east with respect to the Sunda plate at a velocity of approximately 60-65 mm/yr. The Indonesian authorities issued a tsunami warning after a quake struck at 5.15 am with an epicentre 75 km southeast of Sinabang on Simeuleu Island off the western coast of Aceh province, and 215 km from Medan, the largest city on Sumatra.

On the basis of the currently available fault mechanism information and earthquake depth, it was likely that this earthquake occurred along the plate interface.

Dissemination
The first bulletin from the Tsunami Warning Centre with earthquake information and tsunami evaluation was sent within five minutes of this quake. Mail was sent to all Regional Tsunami Watch Providers (RTWP) contacts, and SMS and faxes were sent to all others concerned. The first bulletin was issued with the preferred magnitude 6.6 mb and within minutes the preferred magnitude changed to 7.8 Mw.

[22] Co-ordinated Universal Time is a time standard based on International Atomic Time (TAI) with leap seconds added at irregular intervals to compensate for the Earth's slowing rotation.
[23] Nias is located in a chain of islands parallel to the coast that are separated from Sumatra by the Mentawai Straits; Simeulue is located about 140 km northwest, and the Batu Islands are located about 80 km southeast. This chain, which resurfaces in Nusa Tenggara in the mountainous islands of Sumba and Timor, is the fore arc of the South Sumatra Basin along the Sunda Trench subduction zone (www.thaindian.com/newsportal/ world/magnitude).

The second bulletin disseminated at 04:16:00 IST (31 minutes after the earthquake occurred) with the revised earthquake parameters which was based on PRE-RUN model scenarios. The model indicated that there was no tsunami threat for India. It also indicated that the maximum wave height for this event would not exceed 45 centimetres. With the calculation of estimated water levels at various coastal locations, tide gauges and BPR locations using pre run model, the tsunami arrival time (h) and water level (cm) are estimated.

With the constant analysis from nearby tidal gauges and Bottom Pressure Recorders (BPRs), the model result is compared with the observations. It was noticed that the model predictions of the Tsunami Warning Centre matched very well with the observations.

The Pacific Tsunami Warning Centre (PTWC) issued three bulletins and Japan Meteorological Agency (JMA) issued two bulletins stating the magnitude of the earthquake and other information. The first bulletin of the PTWC was issued at 22:22 UTC with 'Watch' effect for Indonesia. In the third bulletin on April 7 at 00:15 UTC the tsunami 'Watch' was cancelled. The JMA issued the first bulletin at 22:42 UTC and gave the information that 'a local tsunami watch is in effect' and in the second bulletin a Sibolga tide gauge observation of 0.10m was issued.

Box 8: Case Study - Nicobar Island Earthquake

Date and time: 12th June 2010 19:26:47 (UTC)
13th June 2010 00:56:47 (IST)

An earthquake of magnitude 7.5 Mw occurred at Nicobar Islands. It was an undersea earthquake about 160 kms west of Katchall Island with the epicentre at 7.68 N and 91.96 E at a focal depth of 16 kms. INCOIS issued four bulletins for this event and disseminated the information to MHA, MoES, concerned officials in the Andaman and Nicobar Islands and all RTWPs.

Dissemination

The first bulletin was issued within minutes of the earthquake at 01:22:48 IST with details of magnitude and region. The focal depth was 15 km with the water level depth at 3823m. The second bulletin for a tsunami 'Watch' was issued for Nicobar, Komatra and Katchal Island. No major tsunami threat was expected. There was no tsunami threat for the Indian mainland or Indian Ocean.

The third bulletin was issued at 00:56:47(IST); 38 areas of Andaman and Nicobar Island were placed under tsunami 'watch'. The expected tsunami arrival time issued was between 30 to 60 minutes and the water level was expected to be less than 50 cms. The absence of a tsunami threat in the Indian mainland and other parts of the Indian Ocean continued. No immediate action was suggested.

The final bulletin came up at 02:29:53 (IST) where the tsunami 'Watch' issued for Andaman and Nicobar Islands was cancelled.

The PTWC in this event issued three bulletins. In the first bulletin at 19:34 issued 'A Regional Tsunami Watch' for India, Indonesia, Sri Lanka, Myanmar, Thailand and Malaysia. In the second bulletin at 20:18 it continued a local Tsunami Watch for India. Finally in the third bulletin issued at 21:46 the tsunami 'Watch' was cancelled.

The JMA issued a Regional Tsunami Watch Bulletin at 19:47 and a tsunami 'Watch' effect was given for India, Indonesia, Maldives, Sri Lanka, Myanmar, Thailand and Australia. They evaluated that there was the possibility of a destructive regional tsunami in the Indian Ocean.

Impact

The quake shook people from their sleep in Port Blair and briefly disrupted the power supply. There were no reports of causalities or damage to property. The earthquake was felt widely in much of Sri Lanka, in parts of Bangladesh, in Aceh of Indonesia as well as in southern India and along the east coast of India. On the Indian mainland the earthquake was felt in parts of Karnataka, Orissa, Tamil Nadu and West Bengal.

In Orissa, the earthquake was felt by the occupants of high-rise buildings in the cities of Bhubaneswar and Cuttack as well as in the district of Khurda. In West Bengal, the earthquake was mainly felt on the upper floors of high-rise buildings in Dum Dum and Jadavpur in the city of Kolkata. In Karnataka as well, reports were isolated to people who were in the upper floors of buildings in places such as C.V. Raman Nagar and Sadashivnagar in Bengaluru (http://asc-india.org/lib/20100613-nicobars.htm).

The response of the INCOIS in the event was found to be accurate and appropriate. During the entire event, a 'No Threat' Bulletin was issued by the INCOIS to the Indian mainland and other regions of the Indian Ocean which avoided unnecessary evacuation of coastal residents. In doing so it disproved alerts of at least a 'localised tsunami' issued by better-known models from across the world. Timely communication was maintained with the concerned authorities and administration, coastal states and the media. It explained the importance of real-time seismic and sea-level data from other countries to generate timely and accurate tsunami bulletins.

CHAPTER VII
Weather Hazards: Floods

Floods in India are generally caused by a heavy downpour[24], in which the water cannot be disposed off by natural or man-made means. Rains that follow storms and hurricanes are heavy and bring unmanageable amounts of water, causing flash floods or cloudburst floods[25].

In terms of area, over 40 million hectares of the total land in India is prone to floods. Ironically, floods and droughts occur concurrently in different areas of the country. Despite several programmes launched by the Government of India from time to time to minimise these adverse impacts, natural disasters such as droughts, floods, and cyclones continue to haunt millions of people every year. On average in India during 1953 to 2005 the total area affected by floods was 7.6 mn hectares; the average value of damage to crops, houses and public utilities was ₹ 1,805.18 crore. These disasters mainly impact the poor, who are chronically vulnerable in terms of their access to resources, entitlements and livelihood. In fact, the lives of people in the hazard-prone regions, particularly the poor, are almost completely insecure (Dreze and Sen, 1988).

7.1 Types of Floods

There are two principal types of river floods: slow and rapid. The slow kind of flood occurs due to sustained rainfall or rapid snow melt. Drainage obstructions such as landslides, ice, or debris can cause slow flooding upstream. Rapid floods include flash floods that result from convective precipitation (intense thunderstorms) or the sudden release of water from an upstream impoundment created behind a dam, landslide, or glacier.

Another category of floods is coastal floods which are caused by severe sea storms, or as the result of another hazard (e.g., tsunami or hurricane). A storm surge, from either a tropical cyclone or an extratropical cyclone, falls in this category. Catastrophic floods are yet another category which is caused by a significant and unexpected event, such as a dam breakage, or as the result of another hazard, such as an earthquake or volcanic eruption.

7.2 Classification of Flood Situations

To monitor floods in the country, the Central Water Commission (CWC) has categorised flood situations into four categories, depending upon their severity and magnitude. A river is said to be in a "Low Flood" situation when the water level touches or crosses the warning level, but remains below the danger level of the forecasting site. If the water level of the river touches or crosses the danger

[24] There are two monsoon seasons in India: the southwest and northeast monsoons. India receives 80% of its annual rainfall during the southwest monsoon season from June to September. Rainfall in this season also shows a wide range of spatial variation, IMD for this purpose has an extensive rain gauge network and rainfall monitoring system. One of the main functions of IMD's Hydrometeorological Division at New Delhi is the real-time monitoring and statistical analysis of district-wise daily rainfall.

[25] Other types of floods in India are snow-melt floods, monsoon floods of single and multiple events, cyclone floods and floods due to dam bursts / failure.

level, but remains 0.50 m below the Highest Flood Level (HFL) of the site, it is termed a "Moderate Flood" situation. If the water level is below the HFL but still within 0.50 m of the HFL, it is called a "High Flood" situation; in such cases, the CWC issues an "Orange Bulletin" to user agencies, which contains a "special flood message". The flood situation is said to be "Unprecedented" when the water level of the river surpasses the "highest flood level" recorded at any forecasting site so far; in such cases, the CWC issues a "Red Bulletin" to user agencies. All ministries/ departments/ agencies are required to transmit 12-hourly updates for Orange Stage and every three hours for Red Stage.

7.3 Flood Management Measures in India

India formulated its first Flood Policy in 1954, but floods continue to wreak havoc in the country. There is therefore an urgent need for a long-term policy and a plan for flood proofing that is backed by a flood plain management Act[26] as recommended by the CWC (Subbiah, 2004:206). The plan should comprise, among other things, flood risk zoning, prepared by using satellite-based remote sensing, mapping of river configuration and flood control works, estimates of the area likely to be affected by floods, the expected duration of floods, and the measures required for control of floods, and their cost implications. Some important flood management measures adopted in India so far include (i) dams / reservoirs; (ii) embankments ; (iii) drainage channels; (iv) raising the flood level of flood-prone villages; (v) flood forecasting; and (vi) flood relief and rehabilitation. We however have a long way to go before we make substantial progress in resolving the problem. Mass media could play an important role in generating mass awareness about impending floods, droughts, cyclones, and other natural disasters. There is urgent need to devise innovative ways as well so that indigenous methods could be put to use to serve the purpose. There is a need to develop a mass communication strategy and a national campaign to build public consensus on institutional and individual actions with regard to improved disaster management.

7.4 Flood Forecasting Network in India

Flood forecasting has been recognised as the most important, reliable and cost-effective non-measure for flood mitigation. Recognising the importance of this measure, the Reddy Committee set up by the Prime Minister, Government of India suggested flood forecasting of the River Yamuna at Delhi to manage flooding in Delhi. Accordingly in the year 1958, the CWC commenced the flood forecasting service in a small way by establishing a flood forecasting unit for issuing water level forecasts of the River Yamuna for Delhi.[27] On the recommendation of various committees/ panels, a Flood Forecast and Warning Organisation was set up in CWC in 1969 to establish forecasting sites on inter-state rivers at various flood-prone places in the country. 41 forecasting sites were added in 1969, bringing the number of forecasting sites to 43. There has been an extension of the service since

[26] The Act specifies the land use adjustments based on proper planning and employment of techniques for controlling and reducing flood damage. It provides a rational way to balance the advantages and disadvantages of human settlement on flood plains. These adjustments are the key to sound flood plain management.

[27] The CWC started flood-forecasting services in 1958 with the setting up of its first forecasting station on the River Yamuna at Delhi Railway Bridge. At present, the CWC has a network of 175 flood forecasting stations and it operates a vast network of 945 hydrological observation stations and issues level forecasts and inflow forecasts of 28 dam barrage sites located on the main rivers.

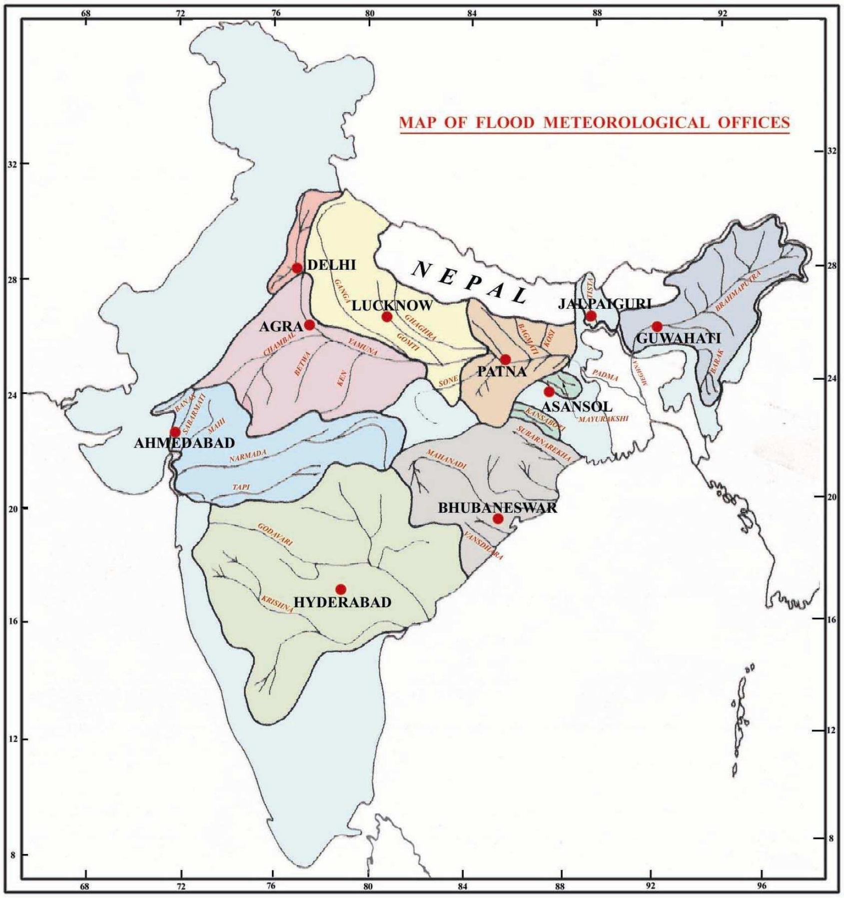
then and now river forecasting has been expanded to cover nine major inter-state flood-prone river basins, which comprises 71 sub-river basins traversing the country. Simple statistical correlations using gauge-to-gauge, gauge and discharge data are being used for some forecasting sites; multiple coaxial correlations using gauge, rainfall, and Antecedent Precipitation Index (API) data are being used for other stations. Mathematical models/ rainfall runoff models like MIKE-11 FF are also in use for some of the sites in the Damodar, Godavari, Mahanadi and Chambal basins. The data received from the site at the divisional headquarters through wireless, telemetry, telephone, etc. is scrutinised and processed. Methods for formulating the forecast depend upon availability of data at the time of framing the forecast, physiographic characteristics of the watershed, warning time available, facilities/ infrastructure available and the purpose of the forecast. For the formulation of flood forecasts, exchanges of data on a real-time basis are made with Nepal, Bangladesh, China, Bhutan and Pakistan. The "Flood Forecasting and Warning System" has played a significant role in reducing the damage cause by floods, helping to reduce the loss of life and movable property. About 6,666 forecasts were issued during the monsoon in the year 2006. The forecasts have an estimated accuracy of 95.8%. A programme is in progress to upgrade and modernise the equipment at the remaining stations (about 787) including the telemetry system in order to improve accuracy in data collection and lead-time in flood forecasting by installing sensor and data logger-based instrumentation like automatic rain gauges, weather stations, and Automatic Water Level Recorders that use the latest technology. Steps are being taken for integration with the state network of flood forecasting and hydrological sites.

7.4.1 Role of IMD and its Services

There are many reputed research and development organisations in India that are engaged in developing appropriate technologies for disaster prevention and mitigation. Their expertise and research output are being used for the benefit of the citizens and vulnerable sections of society. For example, IMD is mandated to monitor and issue warnings regarding tropical cyclones which cause floods in India.[28] Similarly, the CWC has developed a system of flood forecasting and warning. Its network of flood-forecasting stations now covers all the major flood-prone inter-state river basins in the country. Map 1 shows the Flood Meteorological Offices of the IMD in India. The Early Warning System for floods or flood forecasting in India is co-ordinated through 10 Flood Meteorological Offices of the IMD and 166 Flood Forecasting Centres of the CWC (134 for level forecasting and 32 for inflow forecasting}. Forecasts and warnings relating to floods are thus provided by the IMD and CWC of the Ministry of Water Resources.

[28] The monitoring process has been revolutionised by the advent of remote sensing techniques. Satellite-based observations are now used extensively for forecasting and monitoring of cyclones. In India there are two cyclone seasons: pre- and post-monsoon. Commercial jet aircraft equipped with the Aircraft Meteorological Data Relay System are also being increasingly used for data collection. The data are used by the IMD for analysis and forecasting. Detection radars are also being used to provide information about storms. Recently, the IMD has improved its earlier two-stage warning system by adding two more stages – the Pre-Cyclone Watch and the Post-Landfall Scenario. The improved system is very useful for administrators and crises managers (GOI, 2004:7).

Map 1: Early Warning System: Flood Meteorological Offices of IMD



The IMD provides assistance and advice on the meteorological aspects of hydrology, water management and multipurpose river valley project management. It collects hydrometeorological data, which it then transmits to its forecast centres located all over the country. Flood Meteorological Offices (FMOs) have been set up by the IMD at 10 locations, *viz.*, Agra, Ahmedabad, Asansol, Bhubaneshwar, Guwahati, Hyderabad, Jalpaiguri, Lucknow, New Delhi and Patna. This data is analysed and forecasts are formulated including the calculation of the quantitative precipitation forecast. Then the forecasts are disseminated along with heavy rainfall warnings to the Flood Forecast Centres of the CWC. During the flood season, FMOs provide valuable meteorological support to the CWC for issuing flood warnings in respect of the following rivers:

- Agra: Lower Yamuna and Betwa
- Ahmedabad: Narmada, Tapi, Mahi, Sabarmati, Banas and Deman Ganga
- Asansol: Ajay, Mayurakshi and Kangsabati
- Bhubaneshwar: Mahanadi, Brahmani, Baiterini, Bruhaba-lang, Subernarekha, Rushkulya and Vansdhara
- Guwahati: Brahmaputra and Barak
- Hyderabad: Godawari and Krishna
- Jalpaiguri: Teesta

- Lucknow: Ganga, Ramganga, Gomti, Sai, Rapti Ghagra and Samda
- New Delhi: Upper Yamuna, Lower Yamuna, Sahibi
- Patna: Kosi, Mahananda, Baghmati, Kamla, Gandak, Buri Gandak, North Koel, Kanhar, PunPun and Upper Sone

These services of the IMD are also used by the Ministry of Agriculture, Ministry of Water Resources, the Railways, Damodar Valley Corporation Flood Control Authorities and state governments. However, a better physical infrastructure for hydrometeorological activities and data processing and management systems can result in enhanced quality and quantity of rainfall data. As a result, the IMD has undertaken projects to enhance its infrastructure; one example is the 6-year World Bank-aided hydrology project which involves eight southern states and five central agencies including the IMD. The IMD plays an important and active role in providing technical guidance to the concerned states and central agencies in procuring and installing standardised equipment, inspecting the existing and new rain gauge stations, and imparting specialised training to personnel at various levels in the states and agencies. There are also specialised units within the hydrometeorology division of the IMD that cater to the needs of specific interests. The Storm Analysis Unit of the IMD provides design estimates for short duration rainfall in different sub-zones of the country for the purpose of railway and road bridge construction. Hydrometeorological data for a number of river catchments are analysed to compute probable maximum storms, return periods of very heavy rainfall and run-off relationships. The Design Storm Unit of the IMD conducts studies to measure rainfall magnitude and its time distribution to be used as the main input for design engineers in flood estimation for hydraulic structures, irrigation projects, dams, etc. on various rivers. Probable maximum precipitation values are also calculated and evaluated for optimum utilisation of water resources. The generalised one-day point PMP maps for different states in India are published by the IMD.

Although floods cause tremendous damage worldwide, most countries do not document or map floods methodically. It has been found that the major flood-prone states in India are Assam, West Bengal, Uttar Pradesh, Orissa and Andhra Pradesh. The major flood-prone basins are the Ganga, Brahmaputra and Mahanadi, where inundation and bank erosion are common problems. Flash floods from Nepal, Bhutan and China are additional problems in the Ganga and Brahmaputra basins. The frequency or probability of a flood is usually described by assigning a recurrence interval to the flood at each gauging station[29]. This is accomplished by statistically evaluating long-term annual peak stream flows at a station.

The Water Balance Unit of the IMD conducts water balance studies in respect of river basins by applying the well-known Thornthwaite techniques for water budgeting and mass conservation principles. The Thornthwaite water balance approach uses an accounting procedure to analyse the allocation of water among various components of the hydrologic system. Inputs to the model are monthly temperature and precipitation. Outputs of the model include monthly potential and actual evapotranspiration, soil moisture storage, snow storage, surplus, and runoff. To conduct glaciological

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[29] Gauging station is a location used by hydrologists or environmental scientists to monitor and test terrestrial bodies of water. Various hydrometric readings are made at gauging stations such as volumetric flow rate, water quality and observations ecology. The location of gauging stations are given in topographical maps.

studies, information is needed on meteorological parameters and snow accumulation in the upper watersheds of the Himalayan rivers. This is done by the Glaciology Unit of the IMD through collection of ground observations, remote sensing techniques and participation in glaciological expeditions. For a better observational network 27 snow and rain gauges (17 in Himachal Pradesh and 10 in Uttar Pradesh) have been installed in the western region of the Himalayas under the Glaciology Scheme.

7.4.2 Dissemination of Forecasts

The only way to fight floods is to identify areas which are flood-prone, try to predict the flood, prepare for it and train and educate people. Floods affect many areas of the national economy. Some areas that need attention are agricultural flood water damage, urban flood water damage, flood damage to commercial, industrial, and residential properties, flood damage transportation and utilities, crop and pasture damage and damage to flat land. There are other problems associated with floods; since water remains stagnant after the flood recedes, source of drinking water get polluted and food rots. People are left with no resources to combat the calamity. Dissemination of information to user agencies, such as civil/engineering authorities of the concerned states, defence, railway/highway authorities, industrial and other important establishments located in the flood-prone areas is done through telephone/ fax/e-mail/special messenger so that they can take advance action to fight the flood and evacuate the population to safer places. Forecasts are given to radio, television and news agencies for the benefit of the population that is likely to be affected by the flood. Daily flood bulletins are hosted on the website www.india-water.com for rapid dissemination.

Box 9: Case Study - Recent Floods in Uttaranchal

Role of Tehri Dam in Managing the Recent Floods in the Uttarakhand Region and Other Places

General

Tehri dam is a 260.5m high earth and rockfill dam constructed across the River Bhagirathi, just downstream of its confluence with the River Bhilangana. It is a multipurpose scheme designed to generate 2000 MW of power (Tehri HPP Stage-I, 1000 MW, commercially operational since September-2006 and Stage II-PSP, 1000 MW, under construction) and provide irrigation to 2.7 lac hectares and stabilisation of 6.04 lakh hectares in the Gangetic plains of Uttarakhand and Uttar Pradesh. Being a large storage dam, it plays a very important role in managing the floods of the River Bhagirathi and mitigating the impact of floods on areas downstream. It is owned by THDCIL which is a joint venture of the Government of India and the state of U.P.

Four head race tunnels feed the two underground power houses of 1000 MW each. To release excess flood flows, a spillway system consisting of a chute spillway, right-bank shaft spillways and left-bank shaft spillways has been provided for a maximum flood of 15,540 cumecs.

The Bhagirathi and Alaknanda rivers are two major tributaries of the River Ganga and from their confluence at Devprayag, the combined discharge of both these rivers forms the River Ganga. Tehri dam is about 45 kms upstream of their confluence at Devprayag. Up to Rishikesh, the Ganga flows through a narrow valley which starts widening after that. The flood plains are quite wide beyond Haridwar. Therefore, the impact of a flood of the River Ganga increases tremendously as it travels downstream of Rishikesh.

Following are the salient features related to reservoir operation and flood management arrangements:

1.	Top of the dam	:	El 839.5 m
2.	Full Reservoir Level (FRL)	:	El 830.0 m

3.	Maximum Reservoir Level (MWL)	:	El 835.0 m
4.	Min. Draw Down Level (MDDL)	:	El 740.0 m
5.	Gross Storage at FRL	:	3540 MCM
6.	Live Storage	:	2615 MCM
7.	Dead Storage at MDDL	:	925 MCM
8.	Design P M F	:	15540 Cumecs
9.	Chute Spillway Crest Level	:	El 815.0 m
10.	Chute Spillway Capacity at MWL	:	5500 Cumecs
11.	Left Shaft Spillways Crest Level	:	El 815.0 m
12.	LBSS Capacity at MWL	:	3900 Cumecs
13.	Right Shaft Spillways Crest Level	:	El 830.2 m (Un-gated)
14.	RBSS Capacity at MWL	:	3800 Cumecs
15.	Installed capacity of Power Plant	:	1000 MW (4 x 250 MW)
16.	Design Discharge of Power Plant	:	576 cumecs (4 x 144 Cumecs)

Monsoon 2010 and Flood Management at Tehri Dam

The monsoon this year set in a little late, indicating that the filling of the Tehri dam reservoir might get affected. Once the monsoon started it remained almost consistent with intermediate incidents of heavy rainfall. The inflows were lower than expected till 16th July; thereafter it started increasing significantly and raised the reservoir level rapidly. Till 20th July the reservoir level was 5 m below the planned level but it reached EL 785.5m on 1st Aug, approximately touching the planned level and the reservoir level rose rapidly during the second week of August. All four machines of the power plant started functioning at full capacity from 10th August 2010, which is considered to be the first step towards inflow management.

The first incident of moderate flood in the rivers Bhagirathi, Bhilanagana, Alaknanda, Ganga and their tributaries was observed between 18th and 22nd Aug. Realising that the rate was more than expected, the chute spillway was put into operation on 20th Aug' 2010, as soon as the reservoir level crossed EL 815m, i.e., the crest level of chute spillway. Inflow in the Tehri dam reservoir reached around 52,500 cusecs (1,500 cumecs) on 22nd Aug, of which only about 28,000 cusecs (800 cumecs) was released into the Bhagirathi from dam, while the rest of the inflow was stored. On 22nd August, the Ganga at Haridwar was flowing at 295m, i.e., 1 m above the danger mark of 294m and the maximum discharge was around 2,66,000 cusecs (7,600 cumecs) with a contribution of only 28,000 cusecs (800 cumecs) from the Bhagirathi. This flood of the River Ganga was causing problems in the low-lying towns of Haridwar and Rishikesh and any excess release from Tehri dam would have increased the severity of the flood. Thus, by storing a discharge of about 24,500 cusecs (700 cumecs) from the Bhagirathi, the flood impact of the Ganga at Haridwar and Rishikesh was mitigated.

Though the chute spillway was in operation, the reservoir levels continued to rise and reached EL 820m, which is the permitted maximum level for this monsoon on 28th August. The second incident of moderate flood in the rivers Bhagirathi, Bhilanagana, Alaknanda, and Ganga and their tributaries was observed from 7th to 9th Sep. Inflow into the Tehri dam reservoir reached 56,000 cusecs (1,600 cumecs) on 8th Sep, of which only about 28,000 cusecs (800 cumecs) was being released into the Bhagirathi from the dam, while the rest of the inflow was stored. On 8th September, the Ganga at Haridwar was flowing 1m above the danger mark with a maximum discharge of around 2,62,500 cusecs (7,500 cumecs) with a contribution of only 28,000 cusecs (800 cumecs) from the Bhagirathi. Thus, by storing a discharge of about 28,000 cusecs (800 cumecs) from the Bhagirathi, the flood impact of the Ganga at Haridwar and Rishikesh was mitigated.

Incessant rains once again started from 17th September in the catchment area of the Tehri reservoir as well as in other parts of Uttarkhand; consequently the river discharges from the Bhagirathi, Bhilangana, Alaknanda and Ganga started increasing rapidly. Observing the imminent flood situation in the River Ganga, THDCIL stored as much water as possible in order to stagger the impact of the Bhagirathi flood on the River Ganga. Though the reservoir level was around EL 825m on 18th September, THDCIL tried to maintain a discharge of only 29,750–31,500 cusecs (850–900 cumecs) from Tehri dam while storing the excess inflow which was continuously increasing and reached around 1,22,500 cusecs (3,500 cumecs) on the night of 19th September. The Ganga River at Haridwar was running approximately 2.3m above the danger mark with a discharge of 4,72,500 cusecs (13,500 cumecs) on 19th September without the impact of the Bhagirathi flood. Rishikesh and Haridwar towns were witnessing the worst floods in 30 years. Most of the low-lying areas along the River Ganga were inundated at Rishikesh, Haridwar and downstream and remained so for about a week.

During the flood of 17th to 21st September; which was more or less similar to the flood of the River Bhagirathi on 2nd September, 1978, the release from Tehri dam was kept as low as possible for the safety of downstream habitation. As the discharge in the River Ganga started decreasing from 21st September, THDCIL decided to gradually increase the discharge from Tehri dam so as to maintain a cushion in the reservoir for another unprecedented flood.

Therefore, Tehri dam played a crucial role in mitigating the floods of the River Ganga which occurred during this monsoon. Had it not been there, the severity of the flood would have increased manifold, because once the river crosses the danger mark, any increase, though not significant, impacts plain areas significantly.
Source: Mr. K.P. Singh, THDC, India Limited.

CHAPTER VIII
Public Weather Services

The purpose of the Public Weather Services Programme (PWSP) is to meet the needs of society by providing comprehensive weather services, with a particular emphasis on public safety and welfare, and to foster a better understanding by the public of the capabilities of their respective National Meteorological and Hydrological Services (NMHSs), and how best to use the services that NMHSs deliver. Therefore, considering the fact that weather information provides immense social benefit to society, three aspects of public weather service were analysed in this study. These are sources of information, frequency of getting information and types of weather information. According to the survey results, 85% of the people got weather information from the radio/TV/AIR/FM which could be termed as the most reliable sources for such information. The second most reliable source is newspapers, which provide weather information to 47% of the people. Also in Mumbai it was found that 12% of people got weather information through the Internet/e-mail, while 8.3% of the people did not receive any such weather information.

Table 8.1: Sources of Weather Information for the General Public

(percent)

Source	City						All
	Delhi	Kolkata	Mumbai	Bangalore	Hyderabad	Chennai	
Newspaper	38	38	50	32	78	48	47.3
Telephone	4	0	0	0	0	0	0.7
Police Wireless	2	0	0	0	0	0	0.3
Internet/ email	6	4	12	0	6	6	5.7
Websites	0	2	2	0	4	6	2.3
Radio/TV/FM/AIR	62	80	78	92	100	98	85
Mobile	0	0	24	0	6	0	5
Other (specify)	8	0	0	0	0	0	1.3
Do not receive weather information	30	0	16	4	0	0	8.3
Total Number	**50**	**50**	**50**	**50**	**50**	**50**	**300**

Regarding frequency, 61.3% of the people reported that they got weather information daily, while 20.7% said that they receive such information every week. There is also a category of people which have never got such information and these constitute 8.3% of the total sample.

Table 8.2: Frequency of using Weather Information

(percent)

	City						All
	Delhi	Kolkata	Mumbai	Bangalore	Hyderabad	Chennai	
Everyday	44	50	56	52	78	88	61.3
Every week	16	24	22	46	8	8	20.7
Every fortnight	6	22	4	0	14	2	8
Every month	4	4	0	0	0	2	1.7
Never	30	0	18	2	0	0	8.3
Total	50	50	50	50	50	50	300

As far as type of weather information is concerned, most people (83.7%) receive information about rainfall. This information is also considered most useful amongst all the information provided by the IMD. Information on heat/temperature is considered equally useful by 76% of the people. Many people in the survey do not receive information on cold weather as they do not find it useful, primarily because they either could not understand the message or the message was hurriedly transferred to the recipient. The usefulness of weather information was judged on the basis of health-related issues, effect of the information on travel plans and reduction /control of accidents.

Table 8.3: Type and Usefulness of Weather Information

(percent)

Weather Received	Yes	Useful	No	Not Useful
Heat/Temp	76.0	93.4	24.0	6.4
Rainfall	83.7	93.6	16.3	6.4
Cold weather	42.0	88.9	58.0	11.1
Cyclone	55.3	91.0	44.7	9.0
Flood	50.7	91.4	49.3	5.2

Table 8.4: Benefits from Public Weather Services

(percent)

	City						All
	Delhi	Kolkata	Mumbai	Bangalore	Hyderabad	Chennai	
Helps in making travel plans	72.1	68.2	62.5	97.9	20.4	85.7	66.8
Helps in reduction/ control of accidents	23.3	36.4	20.8	89.4	20.4	94.3	49.1
Helps in taking care of health	67.4	68.2	70.8	93.6	40.8	91.4	71.4
Helps in organising events	55.8	9.1	4.2	14.9	55.1	60	37.3
Disaster/ Risk mitigation	14	13.6	4.2	8.5	18.4	28.6	15
Other (specify)	0	0	29.2	2.1	16.3	0	7.3
Total Number	**43**	**22**	**24**	**47**	**49**	**35**	**220**

In other words, public weather services provide the public with warnings, forecasts and other meteorological information for the safety of life and property, as well as for day-to-day convenience, in a timely and reliable manner. Consequently, any public weather service programme must include a system to evaluate whether this task is being fulfilled and to regularly assess the programme's performance. The aim of the evaluation is two-fold: first, to ensure that warnings and forecasts are accurate and skilful from a technical viewpoint, and, second, to ensure that they meet user requirements, and that users have a positive perception and are satisfied with the products. The two evaluation components are complementary, since even a highly accurate and skilful forecast will not produce an effective public weather service if it does not respond to user needs.

Mobile technology, especially in the past decade, has proven to be a very effective means for timely delivery of weather warnings and information to people on the move. Such devices are particularly suited for warning of rapidly developing hazards such as thunderstorms and flash floods. Short message service (SMS) can be pushed to users anytime and anywhere to prompt them to take appropriate precautions. The high rate of use of mobile phones in some places, such as south China, has made it possible for the weather service to issue localised warnings to users geographically located within a particular telecommunications cell. This way, mobile phones become a valuable tool for the delivery of fast and effective warnings.

The **Internet** enables the provision of a variety of weather information and data to individual users. This is especially helpful for sophisticated users who are well-versed with computers and have a good understanding of the weather and of how the information can be used in risk evaluation and decision-making. A recent development arises from the increasing popularity of Wi-Fi in city areas, which makes it possible for people using a portable device to receive automatically the latest site-specific information, for example, temperature and weather from the closest weather station.

8.1 Caring for the Young and Old

It is not sufficient to merely sharpen forecasting skills and enhance technical capabilities. They must also work with people and stakeholders to raise their awareness of weather hazards, and to ensure their understanding of the meaning of warnings and the appropriate response actions to take. In delivering the warning services, importance must be given to the underprivileged, including the elderly and the young, such as warnings on extreme temperatures, namely, very hot and cold weather. These warnings cater to the sick and elderly who are particularly vulnerable to extreme weather, sometimes necessitating the activation of social welfare personnel and opening of shelters by municipal authorities.

Different activities must take the form of public talks and lectures, exhibitions and campaigns, publication of pamphlets and publicity videos, articles in the print media, and organising open days, school talks and joint events with non-government organisations.

8.2 Recent IMD Measures to Improve Public Weather Services

The IMD is currently implementing Phase I of the modernisation programme[30]. Under this programme, upgrading the observing system along with its connectivity with a high-performance computing system, installation of a digitised forecasting platform and dissemination of observations, forecast and warnings in real time to end-users are to be developed by March 2011. This is to be achieved through improved data visualisation, value-addition, and dissemination for better public access/ utilisation through the use of SYNERGIE, which is a powerful tool with a user-friendly interface for the operational meteorology forecaster. With the help of the SYNERGIE tool, meteorological data can be displayed properly, with easy extraction of information and entry of expertised data and any format documents produced by forecasters[31]. Improvement in public weather services and early warning services is thus one of the main objectives of the IMD under this programme.

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[30] See http://moes.gov.in/Parliament/Lok_Sabha/6th_15_2010/unstarred/LU320_6_15_2010.pdf
[31] According to IMD, India may soon have a dedicated weather channel to improve public weather services. In this regard, discussions are going on and a positive response has been received from private players.

The IMD, through this collaboration, aims to serve two purposes: one, to enhance its efficiency and visibility for end-users by improving its warning systems and providing high added-value forecasts to a wider community of users, and two, to affirm its role at the international level.

Météo France International's technical assistance to the IMD for modernisation of its core systems was also within the scope of the project. This included upgrading the telecommunications system through TRANSMET (an automatic message switching system) to exchange observational data with the WMO's Global Telecommunication System, and broadcast warnings to the concerned authorities and media. The two-way use of SYNERGIE is to view and analyse the data and images that are received and to produce warnings as well.

CliSys[32], which is compliant with the WIS approach and is used to build and preserve the country's climatology heritage, provides real-time integration of all data from Automatic Weather Stations and Global Telecom Systems. Other programmes of the project were archiving and upgrading the data processing system through the use of the Central Information and Processing System (CIPS) and the use of the modified version of the METEOFACTORY® system for public weather services and early warning systems.

The IMD recently inaugurated CIPS[33] and a new National Weather Forecasting Centre[34] to improve its public weather service. METEOFACTORY®, which has been adopted in nine countries, is a public weather service system dedicated to end-user production. This arrangement was improved to have a new interface, new functions and new services. One of the advantages of this new METEOFACTORY® is its multimedia mass-broadcasting capability including website, voice server, SMS, e-mail and fax. The product's output format is adapted not only to the broadcasting mode (e.g., txt for an SMS message, html for a website), but also to the user's expectations (e.g., high-definition pdf for the press, multi-page pdf or Open Office Word for hotels, and png in an e-mail for other types of users).

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[32] See http://www.mfi.fr/en/clisys-the-management-tool-for-all-climate-data-fiche-produit.php

[33] CIPS is the core of the modernised IMD distributed information systems. It was commissioned in early July 2010 and is now operational. It provides full meteorological data management capacity to the Government of India, and its open environment enables IMD to schedule tasks leading to new data relevant to forecasting and production.

[34] Due to the availability of the SYNERGIE platforms, the National Weather Forecasting Centre now gathers in a refurbished open space with all working positions related to weather forecasting and warnings as well as end-user production (based on MeteoFactory®) under national responsibility. SYNERGIE has been operational since March 2010 in 12 locations across India.

CHAPTER IX
Summary Conclusions and Recommendations

The overall findings suggest that though farmers, fishermen and the general population are aware of the importance of weather information services provided by the IMD, they are not willing to pay for such services in general. But if such services are provided free of cost, they will use them. Under certain circumstances, people may pay for the services but it would be under compulsion. Therefore, the government should provide such services free of cost to all the sections of people mentioned above. The World Bank (2008) in its study of NMS budgets came to the conclusion that the per country annual budget for NMSs is around 0.03 to 0.05 % of GDP, while the net economic benefits exceed 0.4 to 1.2% of GDP.

The findings suggest that AMF units do not make a significant contribution in reducing cost and increasing income, as districts without an AMFU also perform well in terms of percentage points. Farmers felt that weather information was not very helpful as they could not understand the information and the information was not timely. However, the weather forecast and information seems to make a significant contribution in reducing cost and increasing income in some farming operations. Agriculture and allied sectors are thus the target sector for inclusiveness where efforts are to be made to keep the information simple, clear and timely. Awareness needs to be created among farmers on the utility of weather information in their day-to-day operations as a sizable proportion of the target group still depends on their own or elders′ experience of traditional methods. This can be done through a wide range of media materials, TV shows, etc. Awareness of both Agro Advisory Services (AAS) provided by the IMD and Common Service Centres (CSC) in general is substantially low among the framers and hence efforts should be made to increase awareness of these services.

Awareness and utility of weather information was found to be substantially higher among fishermen for their day-to-day fishing operations.

Since television and radio are the most popular sources of information on weather forecasts, greater emphasis needs to be given to these sources to disseminate weather information. Along with television, new sources of information such as mobile phones and the involvement of NGOs can be used to provide information on weather forecasts to farmers and fishermen. It was also found that the M S Swaminathan Research Foundation (MSSRF) has played a pioneering role in this regard, especially in providing information to the fishing community in India. The IMD thus needs to have a department division to promote relationships with NGOs where farmer leaders like Sharad Joshi and M S Swaminathan should be on the experts′ panel.

Perhaps the IMD and INCOIS should start a similar division for relationship management. It was found that there is a constraint in the use of mobile phones since there are connectivity problems beyond 10 kms. The cyclone-related IMD services were quite appreciated as they are concise and timely. Dissemination of information by INCOIS in case of a tsunami was found very effective as leads could be developed within 5 minutes. Also there is a need for state-specific programmes promoted by the INCOIS keeping in mind the regional differences across India. Gujarat is a leading adopter of such services, while Andhra Pradesh does its own computations of similar services but is ready to receive advisories. Therefore, there can be an effort to assess each state in India on preparedness for weather advisory services which can be done along lines similar to the e-Readiness index. Accuracy, vulnerability and inclusiveness are the important parameters through which such services can be judged. It has been found that improving the accuracy of the estimates will yield results as farmers in group discussions assessed IMD's forecast reliability at around 40 percent (subjective assessment).

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ANNEXURE I
Area of the Study

Districts Selected for the Study of Agromet

Irrigated State	With AMFU	Without AMFU
Punjab	Ludhiana	Jalandhar
Uttar Pradesh (East)	Faizabad	Gorakhpur
Uttar Pradesh (West)	Kanpur	Unnao
Bihar	Samastipur	Begusarai
Uttarakhand	Pantnagar	Haridwar
Rainfed States		
Madhya Pradesh	Sehore	Dewas
Rajasthan	Bikaner	Jaisalmer
Gujarat	Junagarh	Amreli
Maharashtra	Pune	Ahmednagar
Assam	Jorhat	Sibsagar

Districts Selected for the Study of Fishermen

State	District
West Bengal	Kalyani
Andhra Pradesh	Guntur
Tamil Nadu	Nagapattnam
	Puducherry

Districts Selected for the Study of Cyclones

State	District
Andhra Pradesh	Bapatla
West Bengal	Kalyani

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