National Council of Applied Economic Research

Estimating the economic benefits of Investment in Monsoon Mission and High Performance Computing facilities

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Estimating the economic benefits of Investment in Monsoon Mission and High Performance Computing facilities

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We affectionately dedicate this report to Shri R Venkatesan, or Venkatesan Sir as we called him, our mentor and friend, who sadly passed away during the final stages of this study

PREFACE

The National Council of Applied Economic Research has had a long association with the Ministry of Earth Sciences (MoES) in assessing the economic benefits of MoES' initiatives for improving weather forecasts. This report is the fourth product of NCAER's close collaboration with MoES.

Our previous studies have estimated the economic benefits and impacts of MoES initiatives such as its agro-met services, its Low Temperature Thermal Desalination technology, and its dynamic weather and ocean state forecasts. Our 2010 research study assessed the impact and economic benefits of MoES' weather and marine services. Our second research study in 2012 estimated the economic benefits of several services—aviation meteorological services, sea water desalination, ornamental fish culture, and lobster and crab fattening—provided by the MoES organizations, including the National Institute of Ocean Technology, the Indian Meteorological Department, and the Centre for Marine Living Resources and Ecology. The third project in 2015 estimated the economic, environmental, and ecological benefits of providing advisories on Potential Fishing Zones along with Ocean State Forecasts to India's fishing communities. It also estimated the cost of the services provided by Indian National Centre for Ocean Information Services (INCOIS) and National Centre for Medium Range Weather Forecasting (NCMRWF).

This NCAER study examines the economic benefits of investments made in the National Monsoon Mission (NMM) and MoES' High Performance Computing (HPC) facilities and their role in improving the accuracy of monsoonal rainfall predictions. The NMM was setup in 2012 led by the vision of developing a state-of-the-art, dynamic monsoon prediction system for short-, medium-, and long-range rain forecasts. The underlying high-resolution prediction models have been made possible by augmenting HPC capabilities at MoES' Indian Institute of Tropical Meteorology (IITM) in Pune and the NCMRWF in Noida.

These upgraded capabilities have made possible early warnings from MoES anticipating extreme weather events. These have provided the crucial lead time to evacuate millions of people during Cyclone Fani in Odisha in May 2019, Cyclone Amphan in May 2020 in West Bengal, and Cyclone Nisarga in Maharashtra in June 2020, all made possible by these new systems and the timely issue of warnings by IMD.

The NCAER study finds that improvements in IMD's weather forecasts have resulted in massive economic gain to households in rain-fed areas by allowing them to take appropriate action based on accurate weather advisories and avoiding losses that they would have suffered in the absence of timely weather warnings. The NCAER study covered farming, livestock rearing, and fishing households.

I wish to express our gratitude to Dr Parvinder Maini, Program Head, Monsoon Mission and HPC, at MoES for offering her valuable insights during the study, for

connecting the NCAER team to important officials at the MoES institutes, and for her untiring support to the team through the course of the study. The NCAER team had useful meetings at IITM, Pune, at IMD in Delhi and Pune, at NCMRWF in Noida, at the Indian National Centre for Ocean Information Services, the Central Research Institute for Dryland Agriculture, and the International Crops Research Institute for the Semi-Arid Tropics, all in Hyderabad.

I would also like to thank Mr Senthil Kumaran S., Mr Balakumar Sudalaimuthu, Chittibabu Nagulapalli, and their field teams from the Reliance Foundation on Information Services for collating the customised survey data.

This pioneering work was undertaken by a NCAER team led by our Principal Investigators, NCAER Senior Adviser Shri R. Venkatesan and Senior Fellow Dr Poonam Munjal, and including team members Shri Amit Sharma and Devender Pratap, and Dr Shayequa Zeenat Ali. I thank them for their excellent work. I am also very grateful to Dr. N. Ganga Vidya, our consultant for the study, for her role in preparing survey instruments and overall survey execution.

It is with sadness that I note that our dear friend and colleague R Venkatesan passed away suddenly on April 25, 2020 while this study was nearing completion. This study and its bold findings are a fitting tribute to the intellectual leadership and mentoring that Venkatesan provided to generations of NCAER researchers, both while he was a staff member at NCAER and during the last 12 years as a senior NCAER consultant. We proudly dedicate this study to his memory.

July 26, 2020

Dr Shekhar Shah
Director General, NCAER

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The study team is grateful to Dr. Madhavan Nair Rajeevan, Secretary, Ministry of Earth Sciences (MoES) for his useful inputs and pertinent suggestions on the report. We are immensely thankful to Dr Parvinder Maini, Program Head and Scientist G, Monsoon Mission and HPC, Ministry of Earth Sciences, for offering her insights and critical inputs through the course of the study. The team benefited immensely from valuable interactions with officials of the Indian Institute of Tropical Meteorology (IITM), Pune, which helped the research team from NCAER to understand the working of the National Monsoon Mission, and especially the High Performing Computing facilities in detail. We would like to take this opportunity to thank Professor Ravi S. Nanjundiah, Director, IITM, and Mission Director, Monsoon Mission; Dr Suryachandra A. Rao, Scientist G, Associate Mission Director and Programme Manager, Monsoon Mission, IITM; Dr A.K Sahai, Scientist G, Programme Manager, Extended Range Prediction, Monsoon Mission, IITM; Dr Parthasarathy Mukhopadhyay, Scientist F, Programme Manager, Parameterisation and Analysis Group, IITM, and finally Dr Prasanth A. Pillai, Scientist E, Seasonal Prediction Group, Monsoon Mission, IITM.

We are immensely grateful to Dr. E.N. Rajagopal, Scientist G and Head, National Centre for Medium Range Weather Forecasting (NCMRWF); Dr.A. K. Mitra, Scientist G and Group Head, Coupled Modelling, NCMRWF; and Dr. Preveen Devarajan, Scientist G and Group Head, HPC, NCMRWF. Besides their insights on various aspects of NMM and HPC facilities, they explained how both reliability and accuracy of weather forecasts are maintained and how various stakeholders benefit from the weather forecasts for their routine activities.

It would not have been possible for us to carry out this project without the invaluable support from IMD and its officials. We wish to express our gratitude to Dr. M. Mohapatra, Director General of Meteorology, IMD, New Delhi, for providing the overall insights on the functioning of IMD, especially with respect to cyclone warning, of which the important beneficiaries are fishermen and port authorities. Our thanks to Dr. K K Singh, Head, Agromet Services, IMD, New Delhi, for his suggestions on the coverage of the survey conducted for the study and also for connecting the team with the concerned officials at Indian Council of Agricultural Research - Central Research Institute for Dryland Agriculture (ICAR-CRIDA).

We are also deeply grateful to Dr D.S. Pai, Scientist G, Head, Climate Research and Services and Dr R. Balasubramanian, Scientist E, Agroclimate Forecast Division, IMD, Pune, for their valuable insights.

We would like to place on record our appreciation for officials at the Indian National Centre for Ocean Information Services, Hyderabad. In particular, we are thankful to the former Director Dr S.S.C. Shenoi and present Director-in-Charge Dr T.M. Balakrishna Nair for facilitating our visit to their office. We would also like to thank Dr R. Harikumar for offering us a rich discussion and literature on the Ocean State Forecast Services/System and its

usefulness, and data-assimilated numerical models. We are also grateful for the interactions with Dr K. Srinivas, Mr M. Nagaraja Kumar, Dr Sourav Maiti, and Dr Nimit Kumar, which promoted an understanding of the vital role played by Potential Fishing Zones in society. The presentation on the 'Tsunami and Storm Surge Early Warning System' by Mr E. Pattabhi Rama Rao, Head, Tsunami and Storm Surge Early Warning Services Group, and his team members, Mr Ch. Patanjali Rao, Mr B. Ajay Kumar, and Dr P.L.N. Murthy also offered us rich insights into the functioning of weather warning systems.

Thanks are also due to leading scientists at the Central Research Institute for Dryland Agriculture (CRIDA), Hyderabad, especially Dr P. Vijaya Kumar, Dr O. Osman, Dr A.V.M. Subbarao, and Dr S.K. Bal for explaining the methodology for determining rain-fed districts and for sharing the internal documents of CRIDA with the team. The insights offered by them on Agromet advisories and its field level experiments were particularly insightful.

The meetings of the team members at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Patancheru, with Dr Sreenath Dixit, Principal Scientist and Head, and Dr. A.V.R. Kesava Rao, a renowned scientist of agroclimatology, specialising in resilient dryland systems, proved very helpful, especially for conceptualising the questionnaire for the primary survey.

Finally, our appreciation goes out to Mr Senthil Kumaran S., Mr Balakumar Sudalaimuthu, and Chittibabu Nagulapalli, and their field teams from the Reliance Foundation Information Services for collating the customised survey data.

ABBREVIATIONS AND ACRONYMS

Units used in the Report

1 crore = 10 million
1 lakh = 100 thousand

AMFUs	Agromet Field Units
BPL	Below Poverty Line
CAPI	Computer Assisted Personal Interview
CFS	Climate Forecast System
CMFRI	Central Marine Fisheries Research Institute
CRIDA	Central Research Institute for Dry land Agriculture
CWC	Central Water Commission
FRB	Fast Rescue Boat
GKMS	Gramin Krishi Mausam Sewa
GODAS	Global Ocean Data Assimilation System
HPC	High Performance Computing
IASRI	Indian Agricultural Statistics Research Institute
ICAR	Indian Council of Agricultural Research
ICT	Information and Communication Technology
IITM	Indian Institute of Tropical Meteorology
IMD	India Meteorological Department
INCOIS	Indian National Centre for Ocean Information Services
ISMR	Indian Summer Monsoon Rainfall
IVRS	Interactive Voice Response Survey
MoES	Ministry of Earth Sciences
NCAER	National Council of Applied Economic Research
NCEP	National Centers for Environmental Prediction
NCMRWF	National Centre for Medium Range Weather Forecasting
NMM	National Monsoon Mission
NSSO	National Sample Survey Office
OSF	Ocean State Forecasts
PFZ	Potential Fishing Zone
RFIS	Reliance Foundation Information Services
UM	Unified Model

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EXECUTIVE SUMMARY

The National Monsoon Mission (NMM) was initiated by the Ministry of Earth Sciences (MoES) in 2012 with the broad objective to improve the monsoon forecasting skills in the country. NMM builds a working partnership between the academic and R&D organisations, both national and international and strives to improve the forecasting skills by setting up a state-of-the-art dynamic prediction system for monsoon rainfall on different time scales

Four MoES institutes, namely Indian Institute of Tropical Meteorology (IITM), Pune; National Centre for Medium Range Weather Forecasting (NCMRWF), Noida; India Meteorological Department (IMD); and Indian National Centre for Ocean Information Services (INCOIS) have partnered actively in this important and ambitious programme.

The execution and coordination of this mission is undertaken by IITM, which also leads the efforts for improving the extended range and seasonal predictions (for 16 days to one season). For this, IITM is collaborating with National Centers for Environmental Prediction (NCEP), USA and other MoES institutes and is working with the Climate Forecast System (CFS) model. This is a coupled ocean-atmosphere modelling system and combines data from ocean, atmosphere and land for providing long range forecasting. Oceanic initial conditions are provided by INCOIS and atmospheric initial conditions are provided by NCMRWF. Major achievement is the development of seasonal prediction model for monsoons at a very high resolution of 38 kms, extended range prediction (for next 20 days) useful for dry/wet spells, heat/cold wave etc. and a very high resolution ensemble prediction system at 12 kms in the short and medium range (up to 8 to 10 days) useful for extreme weather prediction.

NCMRWF leads the efforts for short and medium range forecasts (for up to 15 days). For this, NCMRWF is collaborating with The Meteorological Office, UK (commonly known as UK Met office) and is working with the Unified Model (UM) for seamless prediction of weather with a special focus on short and medium range forecast of monsoons. This has resulted in improving the prediction skill of short and medium range forecasts by 2 days.

The modelling framework developed by IITM and NCMRWF have been made operational and is being used by IMD for giving forecast in all scales namely short, medium, extended and seasonal. The increased resolution of the models is made possible through timely investments made by MoES for augmentation of the High Performance Computing (HPC) capability at its institutes from 1 PetaFlop[1] to 10 PetaFlops. With this HPC facility, a

[1] *Petaflop: a unit of computing speed equal to one thousand million million (10^{15}) floating-point operations per second.*

paradigm shift in weather and climate modelling activity for operational weather forecasts has been achieved.

This study, undertaken by the National Council of Applied Economic Research (NCAER), examines the economic cost and benefit of the investments made in setting up NMM and HPC facilities and their role in improving the accuracy of prediction of monsoonal rainfall.

The study analyses the macro-level secondary data of production and yield of major crops in the Rain-fed and irrigated areas before and after the implementation of NMM and assesses the likely impact of the NMM on agri-ecosystem.

Also, a primary face-to-face survey of 6098 respondents (comprising farmers, livestock owners and fishermen) and another Interactive Voice Response Survey (IVRS) of about 2 lakh respondents, were conducted to understand the importance of weather-based advisories in decision making, reducing loss and improving livelihoods. This survey also finds out how the Ocean State Forecasts (OSF) and Potential Fishing Zone (PFZ) advisories have aided in increasing incomes of the fishermen by avoiding empty trips and natural calamities, thereby reducing costs. The overall economic benefits are estimated using the information provided in these surveys.

Besides, the study also examines the economic benefits with gender perspective and estimates the gains accrued to the women farmers, livestock owners and fisher-folk due to the improvement in monsoon forecasts.

Macro Observation

The trends, as obtained from the time-series data on production levels of food-grains, show that rain fed agriculture in India has an immense potential to contribute sustainably to the overall food-grain production. This study carried out a regression analysis to examine whether the initiation of the Monsoon Mission in 2012 represents any change in the production levels of food grains. The results of this analysis are as follows:

- There has been a structural change in production for the last 4-5 years. In addition to other factors, this can be attributed to more accurate weather forecast on account of NMM.
- In the irrigated districts, the production level saw a declining trend in the pre monsoon-mission period, which change to an increasing trend in the post monsoon-mission period.
- In case of rain-fed districts, although an increasing trend was observed in both the periods, the rate of increase was much higher in the post monsoon mission period.

Primary Survey

The primary field survey was designed to validate the macro observation. The field survey had the following two segments:

- A face-to-face survey of around 6098 respondents (including 3,965 farmers, 757 marine fishermen and 1,376 livestock owners) to gauge the economic impact of setting up of NMM; and
- An IVRS[2] survey of around 2 lakh respondents to validate the findings of face-to-face survey.

As of year 2018 there are 732 districts of India, out of which we selected 173 districts across 16 states of India. The district sample selection was based on purposive stratified random sampling, taking into consideration the representation of agro-climatic zones, Rain-fed areas, and coverage of different crops and incidence of extreme weather events.

An Agro-climatic zone refers to a geographical area with similar soil types, rainfall, temperature and water availability. The whole of India is divided into 15 major agro-climatic zones, of which 10 zones experience all monsoon events ranging from drought to floods. The sample districts were selected from these 10 agro-climatic zones.

For the identification of rain-fed districts, the rain-fed area prioritization index of the districts has been used. This index was constructed for 499 districts, in a study jointly done by Central Research Institute for Dry land Agriculture (CRIDA) and Indian Agricultural Statistics Research Institute (IASRI), New Delhi. These districts accounted for more than 90 percent of country's population and area. Data on rainfall, available water content, wastelands, ground-water status, irrigation intensity, status of natural resources, rain-fed area etc have been used to construct this index. On eliminating the districts which were considered as priority districts for taking up crop and livestock-based interventions, a total of 173 districts were chosen for the survey. These include the coastal districts and also those which experience extreme rain related events like thunderstorms, cyclones, hail storms and other.

With respect to coverage of crops, the selected districts cover over 70 percent of all major crops. All the major kharif crops – arecanut, banana, brinjal, castor, coconut, fingermillet, ginger, groundnut, jute, maize, mung bean, pearlmillet, pigeon pea, ragi, rice, sorghum, soybean, sugarcane, tapioca, tomato and turmeric have been covered except few plantation crops like cashewnut, coffee and tea. All the Rabi crops- cauliflower, cowpea, gram, green pea, groundnut, lentil, maize, mung bean, mustard, okra, potato, rapeseed, rice, sesame, sorghum, sunflower, urad bean and the most important wheat have been covered.

[2]*The IVRS is a technology that allows the computers to interact with humans through the use of voice and Dual Tone Multi Frequency (DTMF) input via a keyboard. The technology allows access to a vast population of users in a short period of time*

Other than monsoonal rainfall, the study also covers extreme weather parameters which are of great significance in decision making for farmers, fisher folk and livestock owners.

The time-period for which data were collected in the survey was April 2015 to March 2019. This is because IMD has been forecasting monsoon and weather with the new model since 2015.

These surveys were conducted by NCAER in collaboration with Reliance Foundation Information Services (RFIS). The average quantum of benefits realised by farmers in the rain-fed districts due to setting up of the NMM and HPC facilities has been assessed on the basis of the following two characteristics:

- Mitigation of risks; and
- Improvement in income and productivity.

The key findings of the NCAER-RFIS survey are delineated below:

Impact of weather advisories on farmers

- The study interviewed 3,965 farmers across 121 districts of 11 states of India.
- 98 per cent farmers made modifications to at least one of the nine critical practices based on the weather advisories (viz. changed variety/breed; arranged for storage of harvest; early/delayed harvesting; changed crop; early/delayed sowing; changed schedule of ploughing/land preparation; changed pesticide application schedule; changed fertilizer application schedule; and changed scheduled irrigation).
- Making modifications in agricultural practices based on weather advisories help farmers reduce their losses and increase their income. About 94 per cent of farmers who made modifications to any one of the nine critical agricultural practices based on the weather forecast could either avoid loss or saw an increase in income. About 31 per cent farmers made modifications on all nine critical practices.
- The results indicated that the annual income of farmers has a direct relationship with the number of agricultural practices in which modifications were made. For instance, average annual income of farming households which adopted no modification worked out to be Rs. 1.98 Lakh; Rs. 2.43 Lakh for those who modified 1 to 4 practices; Rs. 2.45 Lakh for those who modified 5 to 8 practices and Rs. 3.02 Lakh for those who adopted all the nine changes. It may thus be concluded that the continuous adoption of all the nine critical agricultural practices by farmers based on weather forecasts after 2015 had a significant impact on increasing family incomes of farmers.
- Frequent use of weather advisories were found to increase drastically in 2019, with 59 per cent of farmers reporting their use twice a week. This was only 7 per cent before 2015.
- About 55 per cent of farmers received information on calamities almost every time and 36 per cent of them received correct information occasionally. Of the total farmers who received correct information, 80 per cent reported to have reduced losses occurring due to natural calamities.

Impact of weather advisories on livestock owners

- The study interviewed 1,376 livestock owners across 92 districts of 10 states of India. The survey finds that almost all livestock owners are taking decisions on livestock management practices based on weather forecast, 76 per cent of whom are doing so on all the three practices (viz. modification of shed/shelter; vaccination against seasonal disease; and fodder management).
- About 18 per cent are taking decisions on any two practices, about 6 per cent on any one of the three practices and just 0.3 per cent of all livestock owners were ignoring all the three practices.
- Majority of livestock owners (96 per cent) reported that weather advisories are improving the practice of vaccination against seasonal disease.
- It is reported by 53 per cent of the livestock owners that they received correct information on natural calamity almost every time. Further, 83 per cent of those receiving correct information reported to have reduced losses occurring due to natural calamities.

Impact of weather advisories on fishermen

- The survey covered a total of 757 marine fishermen across 34 districts of 7 states of India. The decision on venturing into sea based on Ocean State Forecast (OSF) advisories for fishing has resulted in substantial reduction in operational cost. About 82 per cent of fishermen reported using OSF advisories every time before venturing into sea while 18 per cent reported using it sometimes.
- Almost 95 per cent of fishermen reported to have avoided empty trips by following OSF advisories. It helped them save a total of Rs. 18.25 crores of operational cost by avoiding venturing into the sea and avoiding 9,606 empty trips during adverse sea conditions which would result in having to return mid-day without any fish catch. Mechanised boat owners are saving relatively higher amount on operational cost (Rs. 39,859) as compared to other boat owners.
- As a result of using Potential Fishing Zone (PFZ) advisories by the surveyed fishermen, a total of 1,079 successful trips were recorded generating additional fish catch (149 by mechanised boat owners, 915 by motorised boat owners and 15 by non-motorised boat owners).
- About 97 per cent of all the surveyed fishermen had received information about latest flood or cyclone on time whereas slightly less than two third (63.4 per cent) of the fisherfolk were affected by the cyclone or flood in some way or the other. However, as high as 86 per cent of them were able to minimize their losses caused by the cyclone/ flood because of the fact that they had received information about the coming cyclone/ flood on time.
- On an average, the fishermen get Rs.17,820 additional income per trip by using PFZ advisories. In total, an additional income of Rs. 1.92 crore was generated from the 1,079 fishing expeditions made using PFZ Advisories.

- It is observed from the data that accuracy of weather forecast and cyclone warnings has significantly increased as 77 per cent of fishermen reported it as always accurate in the recent years as compared to accuracy before 2015.
- About 97 per cent of fishermen reported having received information on the latest natural calamity of which 84 per cent fishermen were able to minimize losses caused by latest calamity.

Economic Benefits of investment made in NMM and HPC facilities

- The estimated number of agricultural households belonging to Below Poverty Line category in the rain-fed areas, is 10.7 million. The agricultural households include both farmers and livestock owning households. This is because livestock owners are subset of farmers, hence there is an overlap in samples of these two activities. Hence the economic impact accrued to these two categories is presented as an aggregate. With an estimated annual income gain of Rs. 12,500 per agricultural household, due to the improvement in weather forecasts after the initiation of NMM, total income gain due to NMM is estimated at Rs. 13,331 crore per annum. The incremental economic benefits in rain-fed districts (accruing to families belonging to "below poverty line" category) for the next 5 years is estimated to be Rs. 48,072 crore.
- Further, with a total of 0.53 million BPL fisher-folk households, the estimated income gain is to the tune of Rs. 663 crore per annum and incremental economic benefit for next 5 years is estimated at Rs. 2391 crore. The incremental economic benefit is estimated for next 5 years as it is assumed that the technology (hardware as well as software) requirements change after every 5 years. Hence, the investment in fixed assets (i.e. HPCs etc.) is expected to be productive only till 5 years.
- These translate to a total economic gain of Rs. 50,463 crore.
- With an investment of Rs. 551 crore made in NMM[3] and Rs. 438.9 crore made in HPC[4], a total of about Rs. 1000 crore has been invested in setting up the augmented infrastructure for weather prediction.
- It is, therefore, inferred that the economic investment of 1 rupee in NMM and HPC facilities realises a 50-fold increase in economic benefits through gains to BPL farming and fishing families.
- With an estimated proportion of women among farmers, livestock rearing and fisher-folk to be 26.9 percent, 48.5 percent and 4.9 percent, respectively, the estimated benefits realized by the women workers works out to be Rs. 13,447 crore, which is 26.6 percent of the total benefit.

[3] *https://pib.gov.in/PressReleaseIframePage.aspx?PRID=1515349 – Press Information Bureau, Ministry of Earth Science, Jan 03, 2018*
[4] *https://pib.gov.in/newsite/PrintRelease.aspx?relid=178346 – Press Information Bureau, Ministry of Earth Science, April 04, 2018.*

I. INTRODUCTION

I.1. Context of the Study

The Green Revolution, which was a boon to Asian agriculture as it saved Asia from food shortages in the 20th century, resulted in high-yielding cereal varieties supported by irrigation schemes and use of fertilizer as an important input. Nonetheless, Rain-fed agriculture continues to be a significant contributor to agriculture production worldwide. According to Rosegrant *et al* (2002)[5], "*although irrigated production has made an increasing contribution to global food production (especially during the Green Revolution), Rain-fed agriculture still produces about 60 percent of total cereals worldwide*". In India, as estimated by Fan and Hazel (2000)[6], about 82 percent of the rural poor live in Rain-fed areas. These people are, therefore, highly vulnerable to any variability in the onset, withdrawal and quantum of rainfall, all of which have a huge impact on agriculture yield, water availability, power generation, ecosystem and economy.

Indian Summer Monsoon Rainfall (ISMR) amounts to more than 80 percent of the annual rainfall over India. It, hence, plays a significant role in the total food production of the country. Having prior knowledge of the variations in monsoon rainfall aids in preparing for droughts and floods and reduces the adverse impacts of the same. The prediction of monsoon rainfall has been attempted since a long time but there has been limited success. In the past, statistical models were used for monsoon prediction but those models were unable to predict extreme weather conditions.

In several advanced countries, weather predictions are done using coupled dynamical models which are run on high-performance computers. But even these models are not good enough to predict variations in ISMR. To properly forecast monsoon, a realistic representation of the earth system processes, such as incoming solar radiation, winds, waves, tides, convection, clouds, soil, vegetation, topography etc. and interactions between them is needed to be modelled using mathematical equations. Some of these processes were not well understood and observed and hence it was a real challenge for the scientists. So, there was a need for a coordinated research work and a focused Mission Mode Program to make any progress. This focused effort on national level for improving the assimilation and forecasting

[5] *Rosegrant, Mark & Cai, Ximing & Cline, Sarah & Nakagawa, Naoko. (2002). The Role of Rainfed Agriculture in the Future of Global Food Production. International Food Policy Research Institute, Washington D.C.*

[6] *Fan, S. and P. Hazel. (2000). Should developing countries invest more in less-favored lands? An empirical analysis of rural India. Economic and Political Weekly 34:1455 – 1464.*

system, especially for the monsoon region, led to the initiation of the "National Monsoon Mission program.

The National Monsoon Mission (NMM) was initiated by the Ministry of Earth Sciences (MoES) with the broad objective to improve the monsoon forecast skill over the country. The NMM builds a working partnership between the academic and R&D organizations, both national and international and improves the forecast skill by setting up a state-of-the-art dynamical prediction system for monsoon rainfall on different time scales. The allocation for the Monsoon Mission for the period 2012-17 was Rs. 400 crores and for the period 2017-20, it was Rs 151 crores (Ministry of Earth Science Press Release, Jan 03, 2018).

The increased resolution of the monsoon mission models are made possible through augmentation of High Performance Computing (HPC) capability at MoES institutes. These HPC facilities not only help in meeting the operational requirements of the MoES but also support the research and development activities in MoES and other academic institutions working in coordination with each other. These facilities were established with huge investment of Rs. 438.9 crore (*Ministry of Earth Science Press release, 04, April, 2018*). Hence, MoES has invested a total of approximately Rs. 1000 crore in setting up NMM and HPC facilities. It is, therefore, imperative that the economic impact of this investment is estimated through evidence-based research.

This study, at the behest of Ministry of Earth Sciences, estimates the economic benefits arising from the National Monsoon Mission and augmentation of HPC facility and their role in improving the accuracy of prediction of monsoonal rainfall.

I.2. Objectives of the Study

This study aims to use a holistic approach to estimate the incremental economic and social benefits subsequent to setting up of the "Monsoon Mission" and investments made in "High-Performance Computing systems". The benefits realized by the below poverty line (BPL) families in Rain-fed districts of farming community, livestock rearers and fisherfolk are accounted for as the returns from these investments. These benefits are expected to have risen out of more accurate weather forecasts which also aids in harnessing the advantages of suitable weather and mitigating of risks associated with adverse (weather) conditions.

The key objectives of this study are the following:

- To examine whether the initiation of NMM has ensured the structural change in production and yield of food grains.
- To estimate the economic benefits arising from the added infrastructure of NMM and HPC facility at MoES institutes.

- To examine their role in improving the livelihood of farming, livestock rearing and fishing communities through improvement in the accuracy of prediction of monsoonal rainfall.
- To understand the importance of weather-based advisories in decision making, reducing loss and improving livelihoods of farmers, livestock owners and fishermen.
- To assess how the Ocean State Forecasts (OSF) and Potential Fishing Zone (PFZ) advisories have aided in increasing incomes of the fishermen by avoiding empty trips and natural calamities, thereby reducing costs.
- To examine the economic benefits with gender perspective and estimate the gains accrued to the women farmers, livestock owners and fisherfolk due to the improvement in monsoon forecasts.

The sections which follow present a brief description of NMM and HPC capacities, further followed by the list of data sources used and broad methodology adopted in the study to meet the study objectives.

I.3. About National Monsoon Mission

The Ministry of Earth sciences (MoES) launched the "Monsoon Mission" in 2012 to develop a dynamical prediction framework and to improve monsoon prediction skill. Four MoES institutes, namely Indian Institute of Tropical Meteorology (IITM), Pune; National Centre for Medium Range Weather Forecasting (NCMRWF), Noida; India Meteorological Department (IMD); and Indian National Centre for Ocean Information Services (INCOIS) partnered actively in this important and ambitious program.

Monsoon mission was focused on the following major objectives:

- To build a working partnership between the Academic and Research& Development Organizations, both national and international and the MoES to improve the monsoon forecast skill for the entire country.
- To setup a state-of-the-art dynamical modelling frame work for improving prediction skill of (a) Seasonal and Extended range predictions and (b) Short and Medium range (up to two weeks) prediction.

The execution and coordination of this mission is undertaken by the IITM, which also leads the efforts for improving the extended range and seasonal predictions (for 16 days to one season). For this, IITM is collaborating with National Centers for Environmental Prediction (NCEP), USA and other MoES institutes and is working with the Climate Forecast System (CFS) model. This is a coupled ocean-atmosphere modelling system and combines data from ocean, atmosphere and land for providing long range forecasting. Ocean initial conditions are

provided by INCOIS and atmospheric initial conditions are provided by NCMRWF. Major achievement is the development of seasonal prediction model with highest skill for predicting monsoon at high resolution of 38km.

NCMRWF leads the efforts for short and medium range forecasts (for up to 15 days). For this, NCMRWF is collaborating with The Meteorological Office, UK (commonly known as UK Met office) and is working with the Unified Model (UM) for seamless prediction of weather with a special focus on short and medium range forecast of monsoons. This has resulted in improving the prediction skill of short and medium range forecasts by 2 days.

Major achievements of Monsoon Mission were the following:

- Development of seasonal prediction model for monsoons at a very high resolution of 38 kms and having the highest skill
- Skillful prediction of monsoon active/break cycles at extended range: at par with the best in the world.
- Very high resolution (27 km) weather forecasts at short and medium range resulting in gain of 2 days lead time.
- Development of a "Unified Model" (UM, adopted from UK Met Office, UK) for high resolution short range & medium range forecasts. The efforts resulted in improving the prediction skill of short and medium range forecasts by 2 days.
- Development of real time Global Forecast System for short range deterministic forecast at 12 km resolution.
- Development of data assimilation system using Global Ocean Data Assimilation System (GODAS) observations.
- Externally funded projects contributed to model developmental and diagnostic studies.

The modelling framework developed by IITM and NCMRWF have been made operational and are being used by IMD for giving forecast in all scales namely short, medium, extended and seasonal scale. IMD used the Monsoon Mission dynamical model, in an operational mode for the first time in 2017, to prepare the seasonal forecast of monsoon rainfall over India. IMD in collaboration with Indian Council of Agricultural Research (ICAR) provides district level agro meteorological advisories to farmers through 130 agro-met field units. As of Jan 03, 2018, about 22 million farmers were receiving crop specific agro-meteorological advisories in vernacular languages. These advisories are used for critical farm operations like management of sowing, changing crop variety, spraying pesticides for disease control and managing irrigation. IMD also provides meteorological support to the Central Water Commission (CWC) for issuing flood warnings.

I.4. About High Performance Computing System

The increased resolution of the NMM dynamic models is made possible through timely investments made by MoES for augmentation of High-Performance Computing (HPC) capability at its institutes from 1 PetaFlop to 10 PetaFlops. With this HPC facility, a paradigm shift in weather and climate modelling activity for operational weather forecasts has been achieved. In order to cater to the needs of modelling activities of Monsoon Mission, an additional 6.8 petaflops-scale HPC facilities are established at two of the MoES institutes:

– "Pratyush" at Indian Institute of Tropical Meteorology (IITM), Pune with computing capacity of 4 peta-flops; and

– "Mihir" at National Centre for Medium Range Weather Forecast (NCMRWF), Noida with computing capacity of 2.8 peta-flops.

Besides their use for advanced dynamic prediction systems, which are used for seasonal, extended and short-range predictions, the HPC systems are also being used for generating probabilistic forecasts for extreme weather. The global weather prediction model has a horizontal resolution of 10 to 12 km and the regional models have much finer horizontal resolution of 3 km and less over the Indian domain. These high-resolution models are also used for prediction of cyclones and other severe weather events with more accuracy and lead time.

These HPC units are the fastest multi-petaflops supercomputers. These are India's largest HPC facility in terms of peak capacity and performance and have brought India's ranking from the 368th position to around the top 30 in the list of HPC facilities in the world. Also, with this, India is now ranked 4th, after Japan, UK and USA on dedicated HPC resources for weather and climate community

The HPC facilities help in the following:

- Generating weather forecasts at block level over India
- High resolution seasonal/extended range forecasts of active/break spells of Monsoon.
- Running Very high resolution coupled models for prediction of cyclones with more accuracy and lead time.
- Ocean state forecasts including marine water quality forecasts at very high resolution.
- Tsunami forecasts with greater lead time.
- Air quality forecasts for various cities
- Climate projections at very high resolution.
- Prediction of extreme weather events with greater accuracy.

I.5. Data Sources for the Study

The study analyses the macro-level secondary data of production and yield of major crops in the Rain-fed and irrigated areas before and after the implementation of NMM and assesses the impact of the NMM on agri-ecosystem. Agricultural statistics on production of selected crops over years were used to assess if there was a structural change in production levels. The data was sourced from the agriculture statistics provided by Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers' Welfare, Ministry of Agriculture and Farmers' Welfare.

In order to obtain the estimated number of farmer households in the Rain-fed districts, the unit level data of the survey conducted by National Sample Survey Office (NSSO)[7] during Jan 2013 to Dec 2013 was used. This 70th round survey is titled as "Situation Assessment Survey of Agricultural Households". It has also been used to prepare the profile of farmers and livestock-owning households and to examine the perception of these households on their access to weather forecasts and whether they have benefited from the same.

The Central Marine Fisheries Research Institute (CMFRI) 2010 census[8] was used to obtain the estimated number of fishing families which fall under the "below poverty line (BPL)" category.

Also, a primary face-to-face survey of 6098 respondents (comprising farmers, livestock owners and fishermen) and another Interactive Voice Response Survey (IVRS) of about 2 lakh respondents were conducted to understand the importance of weather-based advisories in decision making, reducing loss and improving livelihoods. This survey also finds out how the Ocean State Forecasts (OSF) and Potential Fishing Zone (PFZ) advisories have aided in increasing incomes of the fishermen by avoiding empty trips and natural calamities, thereby reducing costs. The overall economic benefits are estimated using the information provided in these surveys.

I.6. Structure of the Report

This report is structured as follows. The present chapter gave the context and objectives of the study and a brief description of NMM and HPC facilities, discussing the

[7] *National Sample Survey Office (NSSO), "Situation Assessment Survey of Agricultural Households, 70th Round, 2013", Government of India, New Delhi.*

[8] *Government of India. (2012), Marine Fisheries Census 2010, India, Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries, New Delhi and Indian Council of Agricultural Research, Central Marine Fisheries Research Institute, Kochi.*

different sources of data used in the study. The following chapter presents the findings of the analysis done on the secondary data used in the study to examine the change in production levels of major crops in the rain-fed and irrigated areas before and after the implementation of NMM and assesses the impact of the NMM on agri-ecosystem. Chapter 3 describes the primary survey undertaken for the study, including the sampling plan, sample size and the survey findings. The next and the concluding chapter estimates the economic benefits of the investment made in setting up NMM and HPC facilities, by estimating the economic gains accrued to farmers, livestock owners and fisherfolk. The economic impact with the gender perspective is also presented in this chapter.

II. STRUCTURAL CHANGE IN PRODUCTION LEVELS

The farming community has been benefitting significantly by the weather forecast services provided to them on agriculture related activities. IMD issues these forecasts for next four days under "Gramin Krishi Mausam Sewa (GKMS)" scheme. Based on these forecasts, specific agro-met advisories are prepared in collaboration with 130 Agro-Met Field Units (AMFUs) and are issued twice a week for all the districts in the country. Experimental block level agro-met advisories are also issued twice a week, since 2018.

These advisories are communicated to the farming community through multichannel dissemination systems, like SMSs through mobile phones, Mobile App named as "Meghdhoot", IMD Website, Kisan Portal and conventional media like TV, radio and newspapers. So far, about 42 million farming households are the recipients of the agro-met advisories on regular basis.

These efforts have successfully created awareness among the farmers to take appropriate and timely action based on forecasts, to save the crops against adverse weather situation and also to take benefit of favourable weather conditions for increasing the yield. It can, therefore, be reasonably assumed that the beneficiary farmers have managed to increase the production levels of major food-grains over a period of time, especially in the post-monsoon mission period, as compared with that in pre-monsoon mission period.

This chapter aims at examining the trends in food-grain production over pre-monsoon mission (2011-2014) and post-monsoon mission (2015-2017) years. This is because IMD has been disseminating the monsoon and weather predictions using the new Monsoon Mission model since 2015. An attempt was made to compare the production performance between rain-fed and irrigated districts. However, since there is no clear definition of rain-fed area, we have used a classification provided by ICAR-CRIDA[9] in a study wherein the districts are categorised based on various agro-climatic parameters such as annual rainfall, moisture index, percent net irrigated area, dryland climate categories and various area development programmes.

The ICAR-CRIDA had designed and built this database to aid scientific and agricultural research. This database helps scientists, working in the areas of socio-economic and policy research and natural resource management in rain-fed areas, especially in selecting rain-fed regions and low productivity regions for sample/case studies. However, the criterion chosen for the categorization of districts was left to the discretion of the user. The study flags those

[9] *District Database of Agricultural Statistics- A Database Management System, Technical Bulletin 01/2014, ICAR-Central Research Institute for Dryland Agriculture, pp 23-42.*

districts where developmental programmes relevant to rain-fed agriculture, like Drought Prone Area Programme (DPAP), Desert Development Programme (DDP) and Rain-fed Area Development Programme (RADP) are in operation. But since there were a number of DPAP/DDP districts where irrigation was also found to be practiced substantially, the study also listed the districts according to their eligibility to these developmental programmes.

For the present study, the production level of food grains in those districts which were identified as eligible for DPAP/DDP in ICAR-CRIDA study (referred as Category I) have been compared with that of districts which were not eligible for any intervention (referred as Category II), as these are assumed to represent the rain-fed and irrigated districts respectively.

This chapter discusses the changes in production level of food-grains in these categories of districts during pre-monsoon mission and post-monsoon mission periods. To capture these changes, the data on food-grains, by districts, have been collected from Directorate of Economics and Statistics, Ministry of Agriculture.

The list of districts, eligible for DPAP/DDP (Category I), categorised as rain-fed, is given below:

Table II.1: State-wise list of DPAP/DDP eligible districts in India

State	Rain-fed Districts
Andhra Pradesh	Anantpur, Chittoor, Cuddapah, Kurnool, Prakasam& Vishakhapatnam
Bihar	Jamui
Chhattisgarh	Bastar, Dantewara, Jashpur, Kanker, Kawrdha, Korba, Koriya, Raigadh, Rajnandgaon&Surguja
Daman & Diu	Daman & Diu
Gujarat	Ahmedabad, Amreli, Bharuch, Bhavanagar, Dahod, Dang, Jamnagar, Kutch, Narmada,Panchmahal, Patan, Porbandar, Rajkot &Surendranagar
Himachal Pradesh	Bilaspur, Shimla &Una
Jharkhand	Bokaro, Chatra, Deoghar, Dhanbad, East Singhbhum, Gadva, Giridih, Godda, Gumla,Hazaribagh, Koderma, Lohardaga, Palamu, Ranchi, Sahibganj& West Singhbhum
Karnataka	Bangalore (Rural), Bangalore (Urban), Bidar, Bijapur, Chamarajanagar, Chitradurga, Dharwad, Gadag, Gulbarga, Hassan, Haveri, Kolar, Koppal, Raichur&Tumkur
Kerala	Kollam
Madhya Pradesh	Barwani, Betul, Chhindwara, Dindori, Jhabua, Khargone, Mandla, Ratlam, Rewa, Shahdol, Sidhi&Umaria

State	Rain-fed Districts
Maharashtra	Ahmednagar, Akola, Amravati, Aurangabad, Beed, Buldhana, Chandrapur, Dhule, Gadchiroli, Hingoli, Jalgaon, Jalna, Latur, Nagpur, Nanded , Nandurbar, Nasik, Osmanabad, Parbhani, Pune, Sangli, Satara, Solapur, Wardha, Washim&Yavatmal
Orissa	Angul, Bolangir, Jharsuguda, Keonjhar, Koraput, Nawapara, Nawarangpur, Phulbani, Rayagada&Sundargarh
Rajasthan	Ajmer, Barmer, Bhilwara, Bikaner, Churu, Dungarpur, Hanumangarh, Jaisalmer, Jalore, Jodhpur, Nagaur, Pali, Rajsamand&Sikar
Tamil Nadu	Ariyalur, Dharmapuri, Perambalur, Ramanathapuram&Thoothukudi
Telangana	Adilabad, Mahabubnagar, Medak&Rangareddy
Uttar Pradesh	Chitrakut, Mahoba&Sonbhadra
Uttarakhand	PauriGarhwal
West Bengal	Purulia

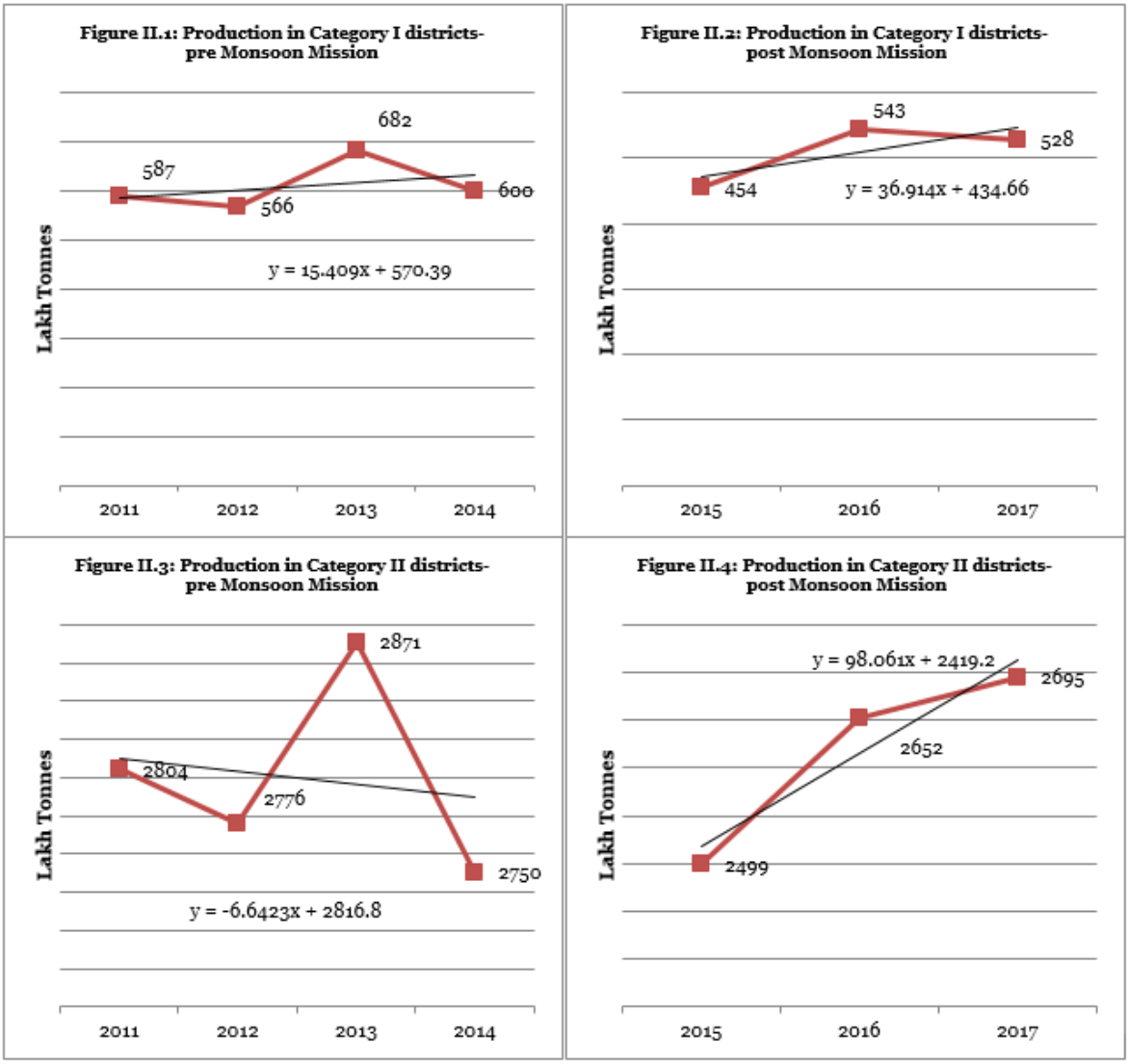
Source: www.dacnet.gov.in

The figures below present cumulative annual figures for total food-grains which include Bajra, Barley, Jowar, Maize, Ragi, Rice, Small millets, Wheat and Other Cereals. Annexure III of this report provides the detailed information on the production level for each crop for the period 2011 to 2017, the period 2011-2014 being considered as "pre-monsoon mission" and that from 2015 to 2017 as "post-monsoon mission". These are provided for both Category I and Category II districts, which represent rain-fed and irrigated districts.

Figures II.1 and II.2 present annual production trends of food grains in Category I districts for the pre and post monsoon-mission periods respectively. Figures II.3 and II.4 present the same for the Category II districts of India. The figures reveal that in Category II districts, the production level saw a declining trend in the pre monsoon-mission period which changes to an increasing trend in the post monsoon-mission period. In case of Category I districts, which represent the rain-fed districts, although an increasing trend was observed in both the periods, the rate of increase was much higher in the post monsoon mission period.

It may also be noted that between 2014 and 2015, there was a significant dip in the overall grain production. It was due to the bad monsoon in 2014 and unseasonal rains and hailstorms during 2014-15[10], adversely affecting the kharif and rabi crops.

[10] https://economictimes.indiatimes.com/news/economy/indicators/indias-foodgrain-output-fell-4-66-in-2014-15/articleshow/48515634.cms?from=mdr



Source: NCAER computations using Agriculture statistics by Directorate of Economics and Statistics, Department of Agriculture, Cooperation and Farmers' Welfare

Note: Category I districts are DPAP/DAP eligible districts and hence represent rain-fed districts

The trends show that regardless of category, performance of all the districts improved in the post-monsoon mission period indicating that there has been a structural change in food grain production.

III. PRIMARY SURVEY OF FARMERS, LIVESTOCK OWNERS AND FISHERMEN

A combination of various factors such as improvements in accuracy of forecasts due to better initial conditions, coupled ocean-atmosphere modelling system which combines data from ocean, atmosphere and land, adequate gestation period for dissemination of data etc. result in outcomes such as mitigation of risks and/or an improvement in productivity and incomes.

To validate these outcomes, a primary face-to-face survey was conducted in order to examine the impact of improvement in weather predictions, resulting from Monsoon-Mission. The survey was conducted by NCAER in collaboration with the Reliance Foundation Information Services (RFIS), which provides validated information services to different livelihood information seekers using modern Information and Communication Technologies (ICT). A collaborative effort was made with various agriculture and allied universities to facilitate data collection from the farmers, livestock owners and fishermen from sample places.

Another Interactive Voice Response Survey (IVRS) of about 2 lakh respondents, was also conducted to understand the importance of weather-based advisories in decision making, reducing loss and improving livelihoods. These surveys also find out how the Ocean State Forecasts (OSF) and Potential Fishing Zone (PFZ) advisories have aided in increasing incomes of the fishermen by avoiding empty trips and natural calamities, thereby reducing costs.

III.1. Objectives of the Primary Survey

The broad objectives of the survey were as follows:

- To understand the importance of weather-based advisories in decision making, reducing loss and improving livelihoods
- To study the significant outcome of the usage of weather-based agro-advisories
- To assess the performance of weather-based agro-advisories in the livelihood of farmers, fishermen and livestock farmers in terms of reducing losses and improving livelihood

III.2.Survey Methodology

The survey questionnaires (given in Annexure I) were developed by NCAER in discussions with RFIS, IMD (India Meteorological Department), CRIDA (Central Research Institute for Dryland Agriculture), INCOIS (Indian National Centre for Ocean Information Services)and IITM (Indian Institute of Tropical Meteorology). The data collection was done among RFIS users through computer assisted personal interview (CAPI) technique.

The information was collected from the farmers and livestock owners in order to understand how the forecast generated under Monsoon Mission has been effective in the districts, which come under the arable as also the drought prone areas. Information was also collected from fishermen in the coastal districts in all the states of the peninsula.

IMD has been disseminating the monsoon and weather predictions using the new Monsoon Mission model since 2015. Hence the study collected data from farmers, livestock owners and fishermen for reference period from April 2015 to March 2019. Beneficiaries selected were those who have been engaged with the RFIS programme for more than three years.

III.2.1. Sampling Plan

As of year 2018 there are around 732 districts of India, out of which 173 districts spread across 16 states of India, were selected by purposive stratified random sampling. This purposive sampling took into consideration the following criteria:

1. Agroclimatic Zones
2. Rain-fed Area
3. Coverage of Crops
4. Incidence of extreme weather events

Agro-climatic zones refer to the geographical area with similar soil types, rainfall, temperature and water availability. India is divided into 15 major agro-climatic zones, of which 10 zones experience all monsoon events ranging from drought to floods. The sample districts were selected from these 10 agro-climatic zones. These 10 zones are:

1. Lower Gangetic Plains Region,
2. Middle Gangetic Plains Region,
3. Upper Gangetic Plains,
4. Eastern Plateau and Hills Region,
5. Central Plateau and Hills Region,
6. Western Plateau and Hills Region,

7. Southern Plateau and Hills Region,
8. Eastern Coastal Plains and Hills Region,
9. Gujarat Plains and Hills Region and,
10. Western Coastal Plains and Ghats Region.

For the selection of rain-fed districts, the Rain-fed Area prioritization index (RAPI) has been used. This index was developed in a study jointly done by Central Research Institute for Dry land Agriculture (CRIDA) and Indian Agricultural Statistics Research Institute (IASRI). The study used data on rainfall, available water content, wastelands, ground- water status, irrigation intensity, status of natural resources, rain-fed area etc to construct the Rain-fed Area prioritization index. The study classified top one-third districts (that is, 167 districts) as high priority rain-fed districts for taking up crop and livestock-based interventions. Of the remaining 333 districts, 173 districts were chosen for the survey. These districts cover the coastal districts and also experience extreme rain related events like thunderstorms, cyclones, hail storms and other.

With respect to coverage of crops, the selected districts cover over 70 percent of all major crops. All the major kharif crops – arecanut, banana, brinjal, castor, coconut, fingermillet, ginger, groundnut, jute, maize, mung bean, pearlmillet, pigeon pea, ragi, rice, sorghum, soybean, sugarcane, tapioca, tomato and turmeric have been covered except few plantation crops like cashewnut, coffee and tea. All the Rabi crops- cauliflower, cowpea, gram, green pea, groundnut, lentil, maize, mung bean, mustard, okra, potato, rapeseed, rice, sesame, sorghum, sunflower, urad bean and the most important, wheat have been covered.

Other than monsoonal rainfall, the study also covers extreme weather parameters which are of great significance in decision making for farmers, fisher folk and livestock owners. The sample number of farmers, livestock owners and fishermen across states and selected districts are provided in Annexure II.

III.2.2. Sample size

RFIS has mobile numbers of farmers and fishermen in its centralized database. RFIS filtered out the regular listeners of complete voice message for over 60 per cent of the messages around the year. This apart, these listeners had also called for query clarification on the Toll Free Helpline and/or the audio conference, and other face to face meetings too. From this list of mobile numbers, first beneficiary was randomly selected from each district, after which sampling interval was applied for selecting subsequent beneficiaries.

Table III.1: Sample persons interviewed by activity status and gender

Activity status	Irrigated areas			Dryland areas			Total		
	Male	Female	Persons	Male	Female	Persons	Male	Female	Persons
Farming	2170	176	2346	1518	101	1619	3688	277	3965
Livestock rearing	828	106	934	408	34	442	1236	140	1376
Fisheries	623	2	625	132	0	132	755	2	757
Total	**3621**	**284**	**3905**	**2058**	**135**	**2193**	**5679**	**419**	**6098**

Source: NCAER-RFIS Survey 2019

For the face-to-face survey, in all, 6,098 beneficiaries were surveyed, of which 419 were women. The total sample covered 3,965 farmers, 757 marine fishermen and 1,376 livestock owners. Total sample respondents comprised 64 per cent belonging to irrigated areas and 36 per cent, to rain-fed areas (see Table III.1).

For the Interactive Voice Response Survey (IVRS), information was collected from around two lakh beneficiaries (mass survey). This survey was conducted to validate the findings of 6098 beneficiaries' survey.

Benefits realized by farmers belonging to "Below Poverty Line" category in the Rain-fed area were assessed in three broad categories:

1. Mitigation of risks
2. Improvement of income and productivity
3. Mitigation of risks and improvement of income and productivity

III.3. Key results - Face-to-face Survey

The key survey findings by different parameters are presented in the sections below.

III.3.1. Demographic Profile of all respondents

The following table (Table III.2) presents the percent distribution of 6098 sample respondents by various demographic parameters like age, gender, education profile and family size:

Table III.2: Demographic Profile of survey respondents

Demographics	Farmers	Livestock Owners	Fisherfolk
Total sample covered (N)	3,965	1,376	757
Age of the respondent	Percent distribution		
18-30 years	16.9	19.0	19.6
31-40 years	29.0	32.8	32.9
41-50 years	29.9	28.3	29.1
51 years and above	24.2	19.8	18.5
Total	100.0	100.0	100.0
Gender of the respondent			
Male	93.01	89.83	99.74
Female	6.99	10.17	0.26
Total	100.00	100.00	100.00
Education			
Illiterate	3.3	4.7	8.7
Below primary	5.8	5.4	11.6
Primary	10.2	13.0	19.7
Middle	15.0	23.0	22.7
Secondary	22.2	20.7	21.7
Higher secondary	19.0	14.0	8.3
Diploma, college & above	24.6	19.3	7.3
Total	100.0	100.0	100.0
Family size			
Up to 5 members	65.1	62.4	70.1
6 to 10 members	31.8	34.2	27.1
11 members and above	3.2	3.3	2.8
Total	100.0	100.0	100.0

Source: NCAER-RFIS survey-2019

III.3.2. Key Findings of Survey of "Farmers"

The study interviewed 3,965 farmers across 121 districts of 11 states of India (Refer Annexure II, Table A.1, for sample number of farmers selected from districts). Information was collected on profile of users, medium used to access information services, preparedness measures taken up based on weather advisories, perception on positive impact created by weather advisories, etc.

Profile of farmers

Top 10 crops grown by the sample farmers included Paddy, Wheat, Cotton, Soybean, Groundnut, Maize, Sorghum, Brinjal, Sugarcane and Banana. Paddy was found to be grown by 51 per cent of farmers; Wheat by 28 per cent of farmers; Cotton by 23 per cent of farmers; Soybean by 18 per cent of farmers; and Groundnut by 14 per cent of farmers. Tomato, Chilly, Coconut, Onion, Mustard, Castor, Mango, Cumin, Areca nut and Sesame are the other crops that feature among top 20 crops that are grown by the sampled farmers in various states (Figure III.1).

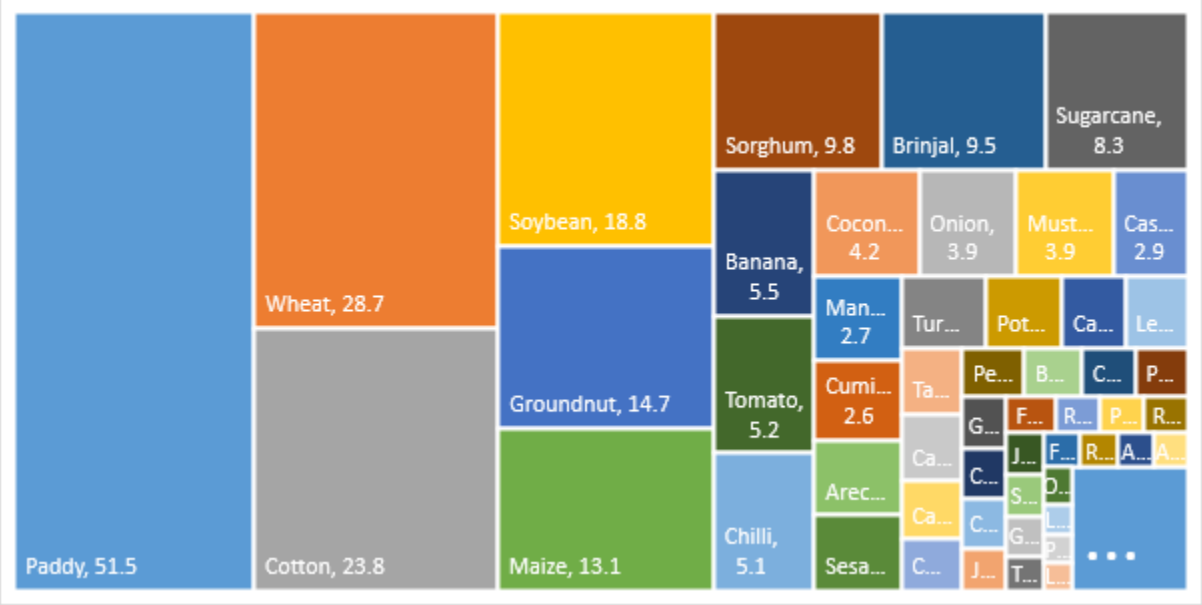
More than 60 per cent of the farmers were either marginal land holders (26.7 per cent) or small land holders (35.7 per cent) (Table III.3).

Table III.3: Land holding profile of farmers

Distribution of farmers based on land classification (%)	
Do not own land	1.8
Marginal farmer (<2.5 acre)	26.7
Small farmer (2.51 to 5.0 acre)	35.7
Medium farmer (5.01 to 12.5 acre)	25.3
Large farmer (More than 12.51 acre)	10.2
Total	**100.0**

Source: NCAER-RFIS Survey, 2019

Figure III.1: Percentage of farmers by type of crops grown



Source: NCAER-RFIS Survey, 2019

The survey assessed the implication of weather forecast on nine critical agricultural practices viz. changed variety/breed; arranged for storage of harvest; early/delayed harvesting; changed crop; early/delayed sowing; changed schedule of ploughing/land preparation; changed pesticide application schedule; changed fertilizer application schedule; and changed scheduled irrigation.

Adoption of weather forecast advisories

Table III.4 presents the proportion of farmers who made changes to each critical practice, and were able to reduce loss and increase income. The modifications done to agricultural practices range from a maximum of 87 per cent in case of Fertilizer Application Schedule and a minimum of 54 per cent in case of Crop Changes.

Findings show that 98 per cent of the farmers made modifications to any of the nine critical practices based on the weather advisories. About 31 per cent farmers made modifications on all nine critical practices (Table III.5).

The survey found that farmers are becoming more weather-sensible now, as almost 99 per cent of the farmers are taking decisions on agricultural practices based on weather parameters. A majority of them also reported their decisions on the application of fertilisers or pesticides followed by the time of sowing and early/late harvesting. The survey also noted trends toward mitigation of risks, which became the driving force for achieving the increased production of food-grain. Reportedly, 94 per cent of farmers who made modifications to any one of the nine critical agricultural practices based on the weather forecast either reduced loss or increased income. Of these farmers, about 26 per cent farmers who adopted all the nine changes were able to avoid losses and another 22 per cent farmers realised an increase in their income.

The family incomes of farmers had increased sharply in consonance with the number of modifications adopted by them based on the weather advisories provided to them. The study found that the annual incomes of farmers had a direct relationship with the changes made to the number of agricultural practices. For instance, the annual income worked out to Rs 1.98 lakh for farming households which adopt no modification; Rs 2.43 lakh for those who modify 1-4 practices; Rs 2.45 lakh for those who modify 5-8 practices; and Rs. 3.02 lakh for those who adopt all the nine changes (Table III.5). It may thus be concluded that the continuous adoption of all the nine critical agricultural practices by farmers based on weather forecasts after 2015 had a significant impact on increasing the family incomes of farmers.

Making modifications in agricultural practices based on weather advisories help farmers in reducing their losses and increasing their incomes. Reportedly, 94 per cent of farmers who made modifications to any one of the nine critical agricultural practices based on the weather forecast either reduced loss or increased income. Of these farmers, about 26 per

cent farmers who adopted all the nine changes were able to avoid losses and another 22 per cent farmers realised an increase in their income.

It is important to note that family income of farmers increased sharply with number of modifications adopted by them based on weather advisory provided to them. Study found that the annual income of farmers has direct relationship with the changes made to number of agricultural practices. For instance, annual income of farming households which adopted no modification worked out to be Rs. 1.98 Lakh; Rs. 2.43 Lakh for those who modified 1-4 changes; Rs. 2.45 Lakh for those who modified 5-8 practices and Rs. 3.02 Lakh for those who adopted all the nine changes (Table III.5).

Table III.4: Percentage of farmers undertaking modifications to their agricultural operations based on weather forecast and its bearing on reduction in loss and increase in income

Critical Agricultural Practices	*% farmers who undertook modifications*	*% farmers who reduced loss and increased income by making changes*
Changed variety / breed	68.2	61.1
Arranged for storage of harvest	71.2	63.3
Early / delayed harvesting	80.2	67.3
Changed crop	53.7	46.1
Early / delayed sowing	79.1	50.3
Changed schedule of ploughing / land preparation	69.2	56.9
Changed pesticide application schedule	86.0	75.2
Changed fertilizer application schedule	86.9	76.3
Changed scheduled irrigation	71.3	60.6

Source: NCAER-RFIS Survey, 2019

Table III.5: Percentage of farmers undertaking modifications on agricultural practices based on weather advisories and their average annual income

No of modifications done to agricultural practices	% of farmers	Average income (Rs.)
None of the modifications done	1.8	1,98,500
Modified 1-4 practices	17.3	2,42,566
Modified 5-8 practices	50.1	2,45,241
Modified all nine practices	30.9	3,02,351

Source: NCAER-RFIS Survey, 2019

Frequency of using weather information

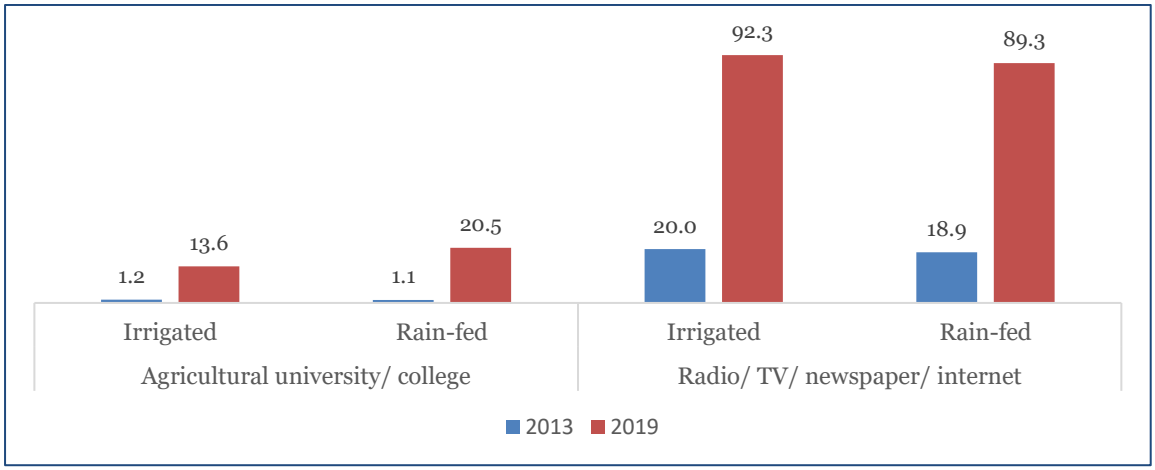
The accuracy of weather information has improved its access and frequency of use over time. In order to draw comparison of current situation, which is captured by NCAER-RFIS survey-2019, with the pre-Monsoon Mission situation, the unit level data of survey conducted by National Sample Survey Office on "Situation Assessment Survey of Agricultural Households" (70th round) during Jan 2013 – Dec 2013[11], were analysed. This survey had collected similar information on access to weather information, its sources and frequency of use of this information.

According to NSS survey, hardly 1.1 per cent of agricultural households belonging to rain-fed areas had access to technical advisories from agricultural universities etc. in 2013, which, according to NCAER-RFIS survey, sharply rose to 20.5 per cent in 2019. Households accessing advisories from radio/ TV/ newspaper/ internet rose from just 18.9 per cent in 2013 to 89.3 per cent in 2019 in dryland areas (Figure III.2). Similar increases are seen in the case of households belonging to irrigated areas as well.

There is a drastic change observed in frequency of use of advisories from pre-Monsoon Mission period (2013) to post-Monsoon Mission period (2019). There were 55 per cent of agricultural households in Rain-fed areas which were using advisories received from radio/ TV/ newspaper/ internet weekly in 2013 which rose to 86 per cent in 2019. The same for irrigated agricultural households increased from 53 per cent in 2013 to 88 per cent in 2019 (Figures III.3 and III.4).This shows increased interest of farmers in using weather advisories due to their positive impact on productivity and production.

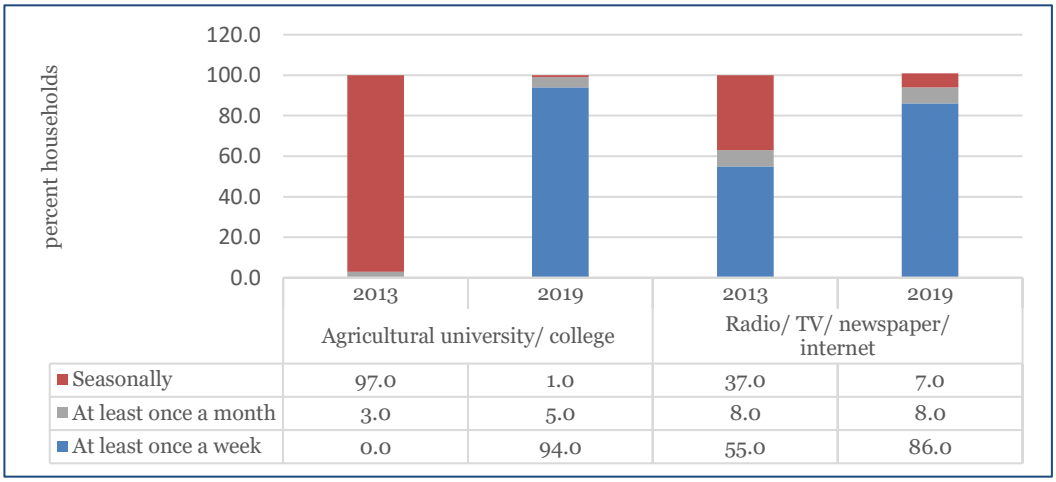
[11] *National Sample Survey Office (NSSO), "Situation Assessment Survey of Agricultural Households, 70th Round, 2013", Government of India, New Delhi*

Figure III.2: Percent households accessing weather advisories in 2013 and 2019



Source: NSS-2013 & NCAER-RFIS- 2019

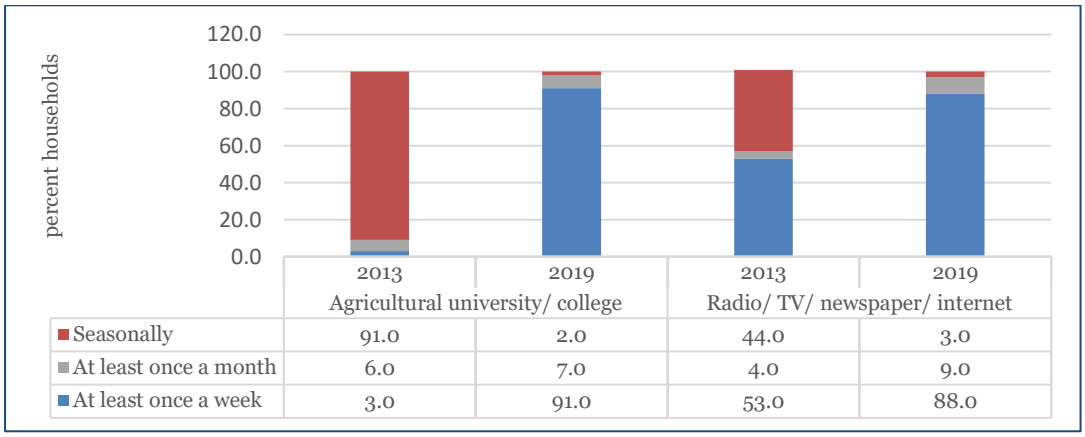
Figure III.3: Percent households by frequency of accessing weather advisories in 2013 and 2019 – rain-fed areas



Seasonally	97.0	1.0	37.0	7.0
At least once a month	3.0	5.0	8.0	8.0
At least once a week	0.0	94.0	55.0	86.0

Source: NSSO-2013& NCAER-RFIS- 2019

Figure III.4: Percent households by frequency of accessing weather advisories in 2013 and 2019 – irrigated areas



	2013	2019	2013	2019
	Agricultural university/ college		Radio/ TV/ newspaper/ internet	
Seasonally	91.0	2.0	44.0	3.0
At least once a month	6.0	7.0	4.0	9.0
At least once a week	3.0	91.0	53.0	88.0

Source: NSSO-2013& NCAER-RFIS- 2019

III.3.3. Key Findings of Survey of "Livestock-owners"

The study interviewed 1,376 livestock owners across 92 districts of 10 states of India (Refer Annexure II, Table A.2 for details). Information was collected on profile of users, medium used to access information services, preparedness measures taken up based on weather advisories, etc.

Profile of Livestock-owners

Almost a third of sample livestock owners were marginal farmers and about 15 per cent were large farmers (Table III.6).

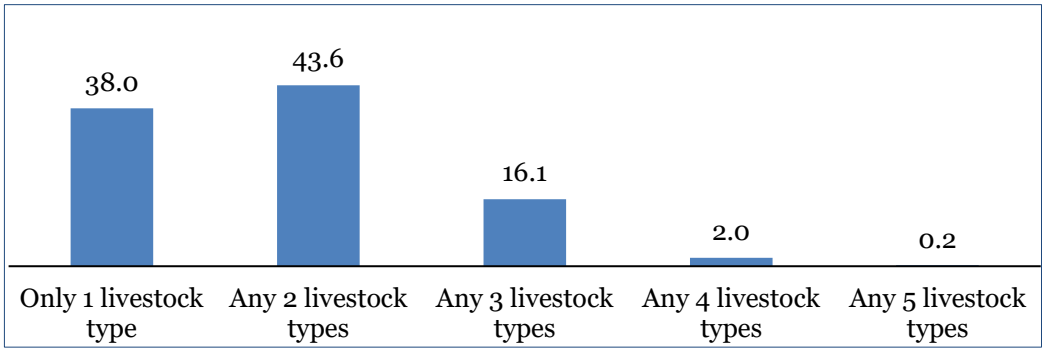
As high as 78 per cent of all the sample livestock owners owned cows, followed by 39 per cent owning buffalos, 20 per cent owning goats and 18 per cent owning poultry. About 38 per cent of them owned just one type of livestock while another 44 per cent owned any two types of livestock (Figure III.5).

Table III.6: Land profile of livestock owners

Distribution of livestock owners based on land classification (%)	
Landless farmer	8.5
Marginal farmer (<2.5 acre)	32.1
Small farmer (2.51 to 5.0 acre)	23.9
Medium farmer (5.01 to 12.5 acre)	20.4
Large farmer (More than 12.51 acre)	14.8
Total	**100.0**

Source: NCAER-RFIS Survey, 2019

Figure III.5: Percentage of livestock owners by number of types of livestock



Source: NCAER-RFIS Survey, 2019

Adoption of weather forecast advisories

Livestock owners are becoming more weather-sensible now, as they take decisions on livestock management practices based on weather parameters. Timely weather-based advisories are helping livestock owners adhere to proper vaccination schedules, fodder practices, and other livestock management practices. The survey found that 76 per cent of the livestock owners were taking decisions on all three practices, viz., modification of sheds/shelters; vaccinations against seasonal diseases; and fodder management (Table III.7). About 18 per cent were taking decisions on any two practices, about 6 per cent were taking decisions on any one of the three practices and just 0.3 per cent of all livestock-rearers were ignoring all the three practices.

A majority of the livestock owners (96 per cent) also reported that weather advisories were having a positive impact on the practice of vaccination against seasonal diseases. About

88 per cent of the livestock-rearers reportedly took decisions related to fodder management and another 87 per cent modified sheds and shelters based on the advisories received.

Table III.7: Percentage of livestock owners taking decision on livestock management practices based on weather or climate forecast

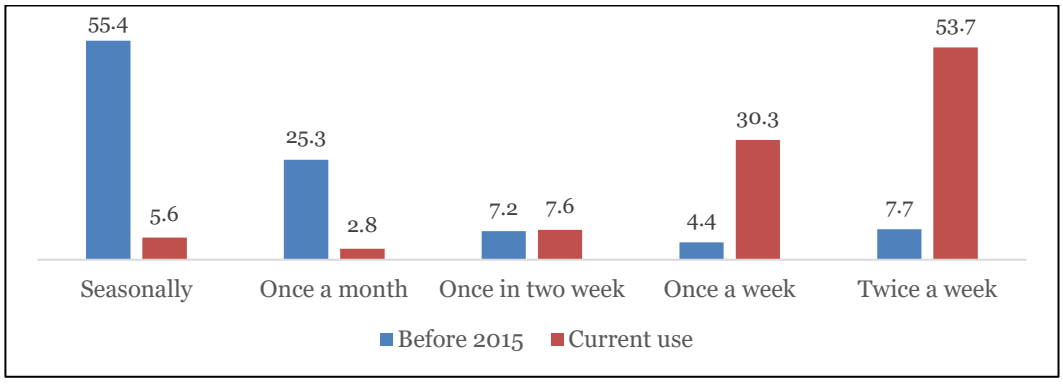
Livestock management practice	% livestock owners
Vaccination against seasonal disease	95.8
Fodder management	87.7
Modification of shed / shelter	86.5
Number of practices on which decisions made based on advisories	**% livestock owners**
Only one of the three practices	6.0
Only two of the three practices	18.0
All of the three practices	76.0

Source: NCAER-RFIS Survey, 2019.

Frequency of using weather information

Survey findings shows that the frequent use of weather advisories has currently drastically increased with 54 per cent of livestock owners having reported using it twice a week. This was only 8 per cent before 2015. It is interesting to note that as high as 55.4 per cent of livestock owners were using weather information only occasionally before 2015 whereas just 5.6 per cent use it occasionally as of the time of survey (Figure III.6).

Figure III.6: Percentage of livestock owners with frequency of using weather information before and after 2015



Source: NCAER-RFIS Survey, 2019

III.3.4. Key Findings of Survey of "Fishermen"

The findings presented in this section are based on interviews of 757 marine fishermen across 34 districts of 7 states of India. Beneficiaries selected are those who have been engaged with the programme for more than three years. Information was collected on profile of users, of type of boat use, medium used to access information services, measures of preparedness taken up based on weather advisories, perception on positive impact created by weather advisories (based on Ocean State Forecast or OSF) etc.

Adoption of OSF advisories by Marine Fishermen

The decision on venturing into sea based on OSF advisories for fishing has substantially impacted the livelihood of fishermen by reducing operational cost. About 82 per cent of fishermen reported using Ocean State Forecast (OSF) every time before venturing into sea while 18 per cent reported using it sometimes. The age-wise analysis reveals that the younger fishermen are more likely to use OSF as compared to their older counterparts. Besides, mechanized boat users are relatively more likely to use OSF than motorized and non-motorized boaters (Table III.8).

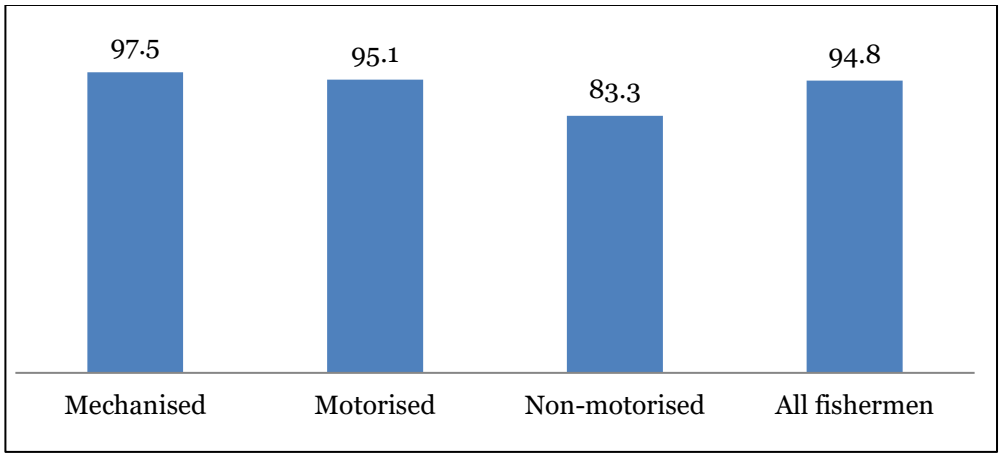
Table III.8: Percentage of fisherfolk using OSF advisories every time before venturing into sea (by age group and type of boat)

Age and type of boat	% fisherfolk who always use OSF advisories
Age of the fishermen	
18-30 years	90.5
31-40 years	85.9
41-50 years	76.4
50 years and above	72.1
Type of boat used for fishing	
Mechanised (trawler, gillnetter, pole & liners)	87.3
Motorised (FRB with outboard motors)	79.0
Non-motorised (catamaran, canoes)	73.3

Source: NCAER-RFIS Survey, 2019

Almost 95 per cent of fishermen reported to have avoided empty trips by following Ocean State Forecast. The majority of mechanised boaters saved empty trips as compared to motorized and non-motorized.

Figure III.7: Empty trips avoided by following OSF



Source: NCAER-RFIS Survey, 2019

As a result, almost 95 per cent of fishermen reported to have avoided empty trips (Figure III.7) by following OSF which helped them save Rs. 18.25 crores of operational cost by avoiding venturing into the sea. They also reported avoiding 9,606 empty trips during adverse sea conditions and having to end up returning mid-day without any fish catch (Table III.9). Mechanised boat owners saved relatively higher amount on operational costs (Rs. 39,859) as compared to other boat owners.

Table III.9: Total operational cost saved due to use of OSF

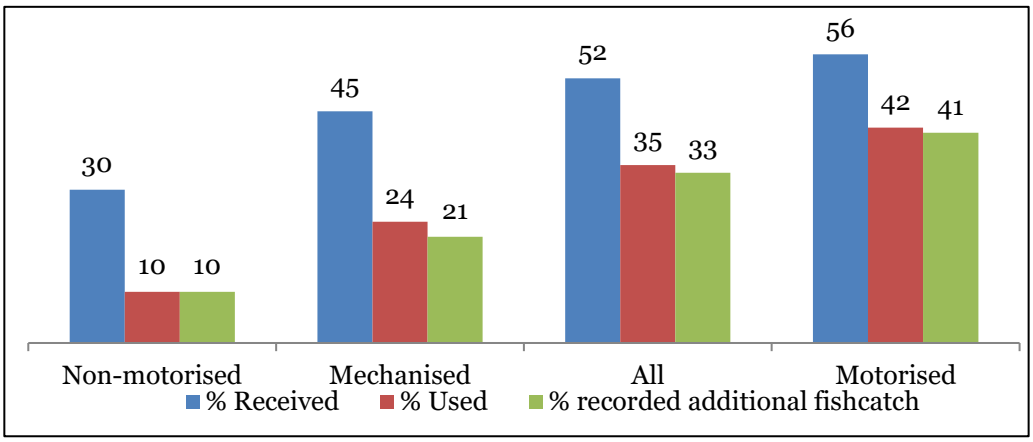
Type of Boat	% of fishermen saving operational cost	No of trips saved in a year	Average operational cost per trip (Rs.)	Total Operational cost saved in a year (Rs crore)
Mechanised	97.5	2,829	39,859	11.27
Motorised	94.2	6,429	10,292	6.61
Non-Motorised	83.3	348	10,389	0.36
All	94.9	9,606	19,003	18.25

Source: NCAER-RFIS Survey, 2019

Adoption of PFZ advisories by Marine Fishermen

Meanwhile, PFZ advisories have been received by 52 per cent of surveyed fishermen and adopted by 35 per cent of them. The adoption rate is relatively higher among fishermen using motorized boat. Of those fishermen who used PFZ advisories, almost 33 per cent reported additional fish catch (Figure III.8).

Figure III.8: Percentage of fisherfolk who received and used PFZ advisories

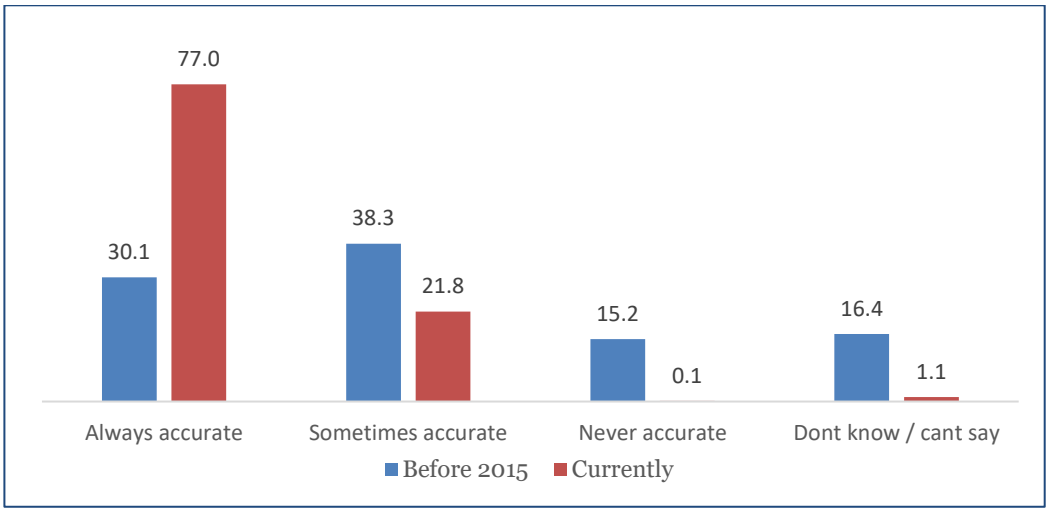


Source: NCAER-RFIS Survey, 2019

Accuracy of cyclone warnings

It is observed from the data that accuracy of weather forecast and cyclone warnings has significantly increased as 77 per cent of fishermen reported it to be always accurate in the recent years (Figure III.9). This is a significant improvement from the perception on accuracy before 2015, as only 30 percent of the respondents reported that the cyclone warnings were accurate before 2015.

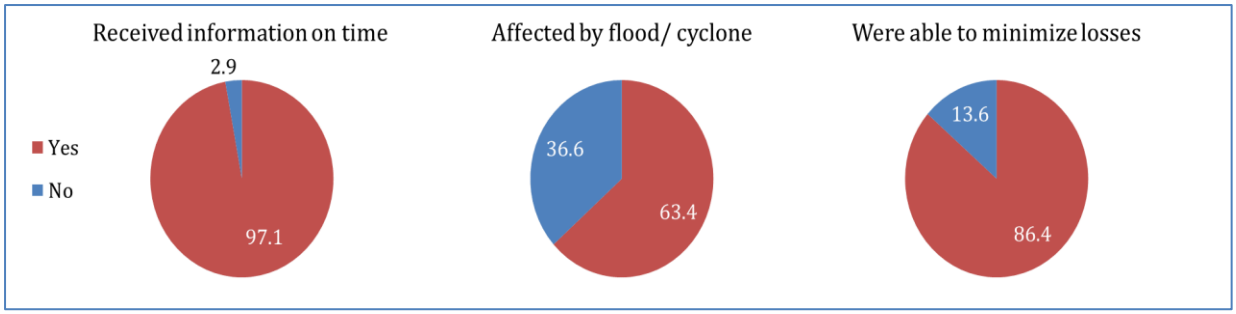
Figure III.9: Percentage of fisherfolk reporting accuracy of weather information before and after 2015



Source: NCAER-RFIS Survey, 2019

The survey results also show that about 97 per cent of all the surveyed fishermen had received information about latest flood or cyclone on time whereas slightly less than two third (63.4 per cent) of the fisherfolk were affected by the cyclone or flood in some way or the other. However, as high as 86 per cent of them were able to minimize their losses caused by the cyclone/ flood because of the fact that they had received information about the coming cyclone/ flood on time. Hence, providing correct information on time has proved economically beneficial for majority of the stakeholders (Figure III.10).

Figure III.10: Percentage distribution of fisherfolk on information related to flood/cyclone

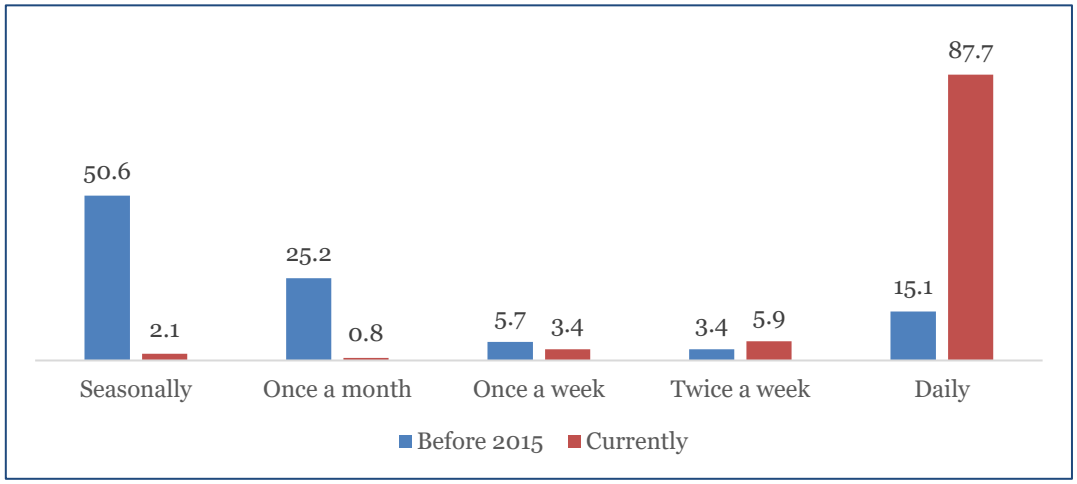


Source: NCAER-RFIS Survey, 2019

Frequency of using weather information

Survey findings shows that much larger proportion of marine fishermen are using weather advisories very frequently, than the proportion of fishermen who used to do so before 2015. As many as 87.7 percent are using these advisories on daily basis, as compared to just 15.1 percent before 2015 (Figure III.11)

Figure III.11: Distribution of fisherfolk by frequency of using weather information before and after 2015



Source: NCAER-RFIS Survey, 2019

As a result of using PFZ advisories by the surveyed fishermen, 1,079 successful trips in total were recorded generating additional fish catch (149 by mechanised boat owners, 915 by motorised boat owners and 15 by non-motorised boat owners). On an average, the fishermen get Rs.17,820 additional income per trip by using PFZ advisories. Income per fishing trip is higher among mechanized boat users as compared to other boat users. In total, Rs. 1.92 crore additional income was generated from the 1,079 fishing expeditions made using PFZ Advisories (Table III.10).

Table III.10: Total additional income generated by using PFZ advisories

Type of Boat	No of trips which recorded additional Fish catch when PFZ advisories were used	Average additional income gained per trip (Rs)	Gross Additional income (in Rs. crore)
Mechanised	149	20,228	0.30
Motorised	915	17,642	1.61
Non-Motorised	15	4,700	0.007
Total	1,079	17,820	1.92

Source: NCAER-RFIS Survey, 2019

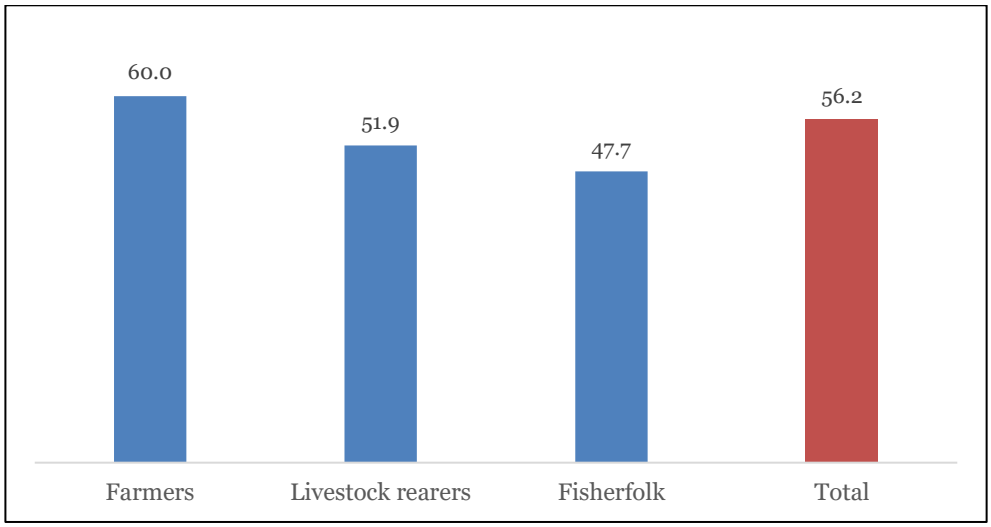
III.4.Key Results - IVRS

Besides the detailed face-to-face survey of 6098 farmers, fisherfolk and livestock rearers, an Interactive Voice Response Survey (IVRS) of around two million beneficiaries (mass survey) was conducted to validate the findings of 6098 beneficiaries belonging to farming/fishing, livestock rearing segments. The IVRS survey also provided an approximate estimation of expected benefits by the agricultural households.

The large sample of two million beneficiaries were asked to respond in a "Yes" or "No" to the question on whether there was any increase in agricultural or livestock income because of the usage of weather information. Further, if yes to this question, they were asked to indicate the level of increase of income. The response rate of IVRS was just about 10 percent across all the categories – farmers, livestock owners and fishermen, so the effective sample size is 2 lakh respondents.

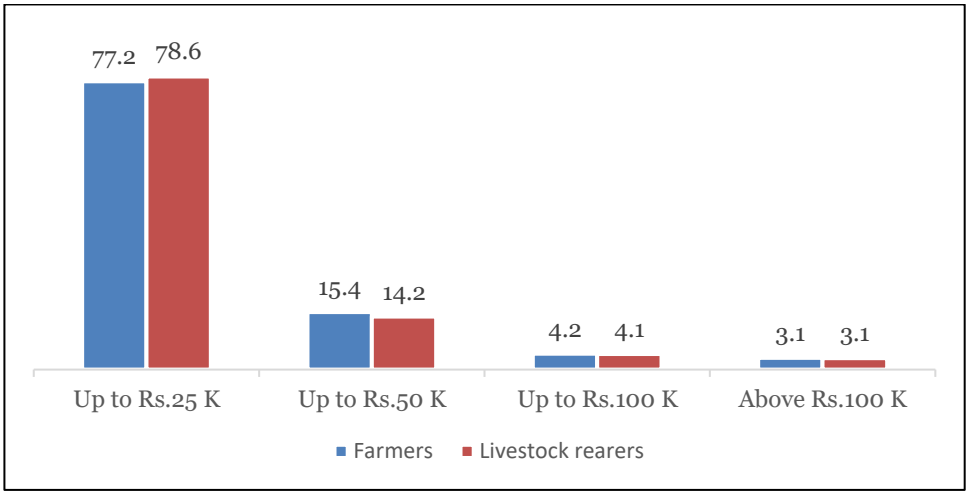
The results reveal that of the total number of beneficiaries who responded to the first question, 56.2 percent answered in the affirmative (Figure III.12). This proportion is the highest in the case of farmers. Further, as high as 77.2 percent farmers confirmed that the level of increase has been up to Rs. 25,000. Among livestock owners, this proportion is even higher at 78.6 percent (Figure III.13)

Figure III.12: Percent respondents responding "Yes" to whether any increase in income due to usage of weather advisories



Source: NCAER-RFIS IVRS – 2019

Figure III.13: Percent distribution of respondents by levels of increase in income



Source: NCAER-RFIS IVRS – 2019

IV. ESTIMATION OF ECONOMIC BENEFITS

Economic benefits of investments made towards Monsoon Mission can be measured in terms of income gains to main stakeholder, that is, farmers in Rain-fed areas, livestock owners and fisherfolk, bulk of whom belong to Below Poverty Line (BPL) category. Economic gains are usually measured in terms of net gain in uncommitted social income in the hands of government. Since BPL income accruing in the private sector is assured to be at par with uncommitted social income in the hands of government, this is often referred to as the "reference" income level to estimate this uncommitted social income.

The primary surveys (face-to-face and IVRS) carried out in this study estimated the average gain in income which the households realized due to the usage of weather information. The surveys also found how the beneficiaries found an improvement in weather information now as compared to that of pre-Monsoon Mission period (before 2015). Due to this improvement, larger number of farmers, livestock owners and fishermen are using the weather advisories and their frequency of usage has also gone up significantly.

Hence, it is reasonable to assume that the average income gains reported by the respondents result from the improved weather information which further is the consequence of investment made in "Monsoon Mission and HPC facilities.

While the average income gain per household is obtained from the surveys, the total estimated income gain can be derived by multiplying this average gain per household by the total number of farming as well as livestock owning households, falling under BPL category.

To obtain the total number of such households, the survey conducted by NSSO in its 70th round and titled "Situation Assessment Survey of Agricultural Households"[12], has been used. This survey provides information on agricultural households belonging to three major activities, namely cultivation, livestock, and non-farm business.

The survey was conducted during the period 1st January, 2013 to 31st December, 2013, to collect information for reference periods which correspond to two halves of the agriculture years - July to December, 2012 and January to June, 2013 - from each sample household.

July to December 2012 round data was collected under visit 1 and January to June 2013 data was collected under visit 2 of the survey. A total of 35,200 households from 4529 villages were surveyed in visit 1 and 34,907 of these households were again canvassed during

[12] *Government of India (2013), "Situation Assessment Survey of Agricultural Households in India (January'2013 - December'2013)", National Sample Survey Office (NSSO), New Delhi.*

visit 2. Estimated number of agricultural households, population and estimated number of persons belonging to agricultural households and involved in agricultural and allied activities in both irrigated and Rain-fed areas for each state are given in Table IV.1 below.

Table IV.1: State-wise estimated number of agricultural households, population and farmers, 2012-13

(thousand numbers)

State	Households			Population			Farmers		
	Irrigated	Rain-fed	Total	Irrigated	Rain-fed	Total	Irrigated	Rain-fed	Total
Jammu & Kashmir	1,128	0	1,128	6,299	0	6,299	2,537	0	2,537
Himachal Pradesh	636	245	881	3,010	1,010	4,020	1,574	580	2,153
Punjab	1,408	0	1,408	7,390	0	7,390	3,012	0	3,012
Chandigarh	1	0	1	4	0	4	2	0	2
Uttaranchal	954	107	1,061	4,662	427	5,088	2,499	234	2,733
Haryana	1,569	0	1,569	9,187	0	9,187	3,402	0	3,402
Delhi	22	0	22	111	0	111	28	0	28
Rajasthan	3,581	2,902	6,484	18,176	16,078	34,253	8,174	6,899	15,073
Uttar Pradesh	17,751	298	18,049	1,01,986	1,688	1,03,673	38,844	601	39,445
Bihar	7,009	85	7,094	38,641	452	39,093	12,190	160	12,350
Sikkim	67	0	67	281	0	281	168	0	168
Arunachal Pradesh	108	0	108	606	0	606	225	0	225
Nagaland	262	0	262	1,436	0	1,436	449	0	449
Manipur	176	0	176	918	0	918	340	0	340
Mizoram	76	0	76	388	0	388	204	0	204
Tripura	244	0	244	1,066	0	1,066	394	0	394
Meghalaya	354	0	354	2,036	0	2,036	914	0	914
Assam	3,423	0	3,423	16,897	0	16,897	6,183	0	6,183
West Bengal	6,138	224	6,362	27,071	925	27,996	10,100	408	10,508
Jharkhand	301	1,933	2,234	1,494	10,175	11,670	488	4,534	5,021
Odisha	3,206	1,288	4,494	14,974	5,987	20,960	6,678	2,831	9,509
Chhattisgarh	1,248	1,313	2,561	6,879	6,395	13,274	3,371	3,399	6,770
Madhya Pradesh	4,670	1,325	5,995	24,432	7,418	31,849	11,256	3,265	14,521
Gujarat	2,012	1,918	3,930	10,644	9,874	20,518	5,529	5,235	10,765
Daman & Diu	0	4	4	0	24	24	0	9	9
D & N Haveli	19	0	19	100	0	100	51	0	51
Maharashtra	1,078	6,019	7,097	5,214	30,135	35,349	2,858	16,193	19,051
Andhra Pradesh	1,623	1,974	3,597	6,152	8,158	14,309	3,347	4,743	8,090
Karnataka	1,839	2,403	4,242	9,417	11,727	21,143	4,564	6,260	10,824
Goa	22	0	22	108	0	108	32	0	32
Lakshadweep	2	0	2	12	0	12	4	0	4
Kerala	1,290	114	1,404	5,548	436	5,984	2,095	185	2,280
Tamil Nadu	2,764	480	3,244	11,132	1,981	13,112	5,552	873	6,425
Puducherry	19	0	19	74	0	74	25	0	25

State	Households			Population			Farmers		
	Irrigated	Rain-fed	Total	Irrigated	Rain-fed	Total	Irrigated	Rain-fed	Total
A & N Islands	26	0	26	132	0	132	70	0	70
Telangana	1,437	1,102	2,539	5,935	4,939	10,875	3,275	2,707	5,982
All India	66,464	23,737	90,201	3,42,412	1,17,827	4,60,239	1,40,434	59,115	1,99,549

Source: NCAER's computations using NSS 70th round data, 2012-2013

IV.1. Economic gains accruing to Farming Community

According to NSSO survey -2012-13, there are a total of 23.7 million agricultural households in rain-fed areas. It may be noted that agricultural households include both farmers and livestock owning households. This is because livestock owners are subset of farmers, hence there is an overlap in samples of these two activities. Hence the economic impact accrued to these two categories are presented as an aggregate.

About 45 per cent of the agricultural households, according to IVRS, are considered to be belonging to BPL category. The estimated income gain reported by these households due to usage of weather advisories is Rs. 12,500 per annum per household. The life of technologies associated with HPC mathematical models is assumed to be 5 years. Hence, the present value computation is done over a period of 5 years.

The discount rate used for present value computations is 12 percent, which is the social discount rate[13]. The annual economic benefits to the farming community (BPL farmers in rain-fed area) works out to be Rs. 13,331 crores. Economic benefits over the next five years works to be about Rs. 48,056 crores for the farming community at 12 per cent social discount rate. The incremental economic benefit is estimated for next 5 years as it is assumed that the technology (hardware as well as software) requirements change after every 5 years. Hence, the investment in fixed assets (i.e. HPCs etc.) is expected to be productive only till 5 years.

IV.2. Economic gains accruing to Fisherfolk

The total fisher-folk population is 4 million as per CMFRI Census (2010)[14] and total fisher-folk households numbered around 0.87 million. The census indicated that about 61 per cent of the fisher-folk fell under the BPL category. Hence, the number of households falling

[13] *The Social Discount Rate is the interest rate used to calculate today's value of the benefits and costs of proposed policies. It is used in computing the value of funds spent on social projects.*

[14] *Government of India. (2012), Marine Fisheries Census 2010, India, Ministry of Agriculture, Department of Animal Husbandry, Dairying and Fisheries, New Delhi and Indian Council of Agricultural Research, Central Marine Fisheries Research Institute, Kochi*

under BPL category worked out to be 0.53 million. Since no data following the survey conducted by CMFRI 2010 is available, these figures have been used to compute the economic benefits accruing to the fishing community from the Monsoon Mission.

The IVRS survey reveals that the average income gain is to the tune of Rs. 12500 per annum per household in the lowest income category. Accordingly, the annual income gained by BPL fisher households work out to be Rs. 663 crore. The present value of benefits accruing to fisher-folk works out to be Rs. 2391 crore over a period of 5 years, with 12 percent social discount rate.

IV.3. Economic impact of Monsoon Mission

On adding up the economic gain accruing to agricultural households and fisher households, the present value of benefits accruing to the BPL households belonging to Rain-fed areas works out to be Rs. 50,447 crore. The current level of investment is far less in comparison to the realizable benefits over the 5 year period.

The investment made on Monsoon Mission phases I and II was Rs. 551.13 crores. In addition, investment made in setting up the HPC facilities was Rs. 438.9 crore. Hence a total of Rs. 990 crore has been invested in augmenting the infrastructure at MoES institutes, to improve the weather predictions.

Hence, the economic investment of one unit in NMM and HPC facilities realizes a 50-fold increase in economic benefits through gains to BPL farming and fishing families. The economic benefits, as described above, are summarized in the table below:

Table IV.2: Economic Benefits of the investment in Monsoon Mission

Economic gain realised by BPL Farmers	
Number of agricultural households in rain-fed areas (districts)	23.7 million
BPL agricultural households in rain-fed areas (45% of total)	10.665 million
Annual income gains (according to NCAER's IVRS survey with Reliance Foundation)	Rs 12,500 per household
Annual income gains due to the Monsoon Mission	Rs 13,331 crore
Incremental economic benefits in rain-fed districts (accruing to BPL families) at 12% social discount rate=Recurring annual income gains to BPL agricultural households x {1/1.12 + 1/1.12^2 + 1/1.12^3 +1/1.12^4 +1/1.12^5} for 5 years	13331x 3.606 = Rs 48,072 crore
Economic gain realised by BPL Fishermen	
Total number of fisher-folk households	0.87 million
BPL fisherfolk households(61% of total)	0.53 million
Annual income gain in the lowest income	Rs12,500 per household
Total Annual income gained by all households	Rs663 crores
Present value of benefits over a 5-year period (with 12% social discount rate)	(Rs663x 3.606)=Rs2391 crores or say Rs 2400 crores
Total economic benefits due to income gains of farmers and fishers =Rs 50,000 crores (approx.)	

IV.4. Economic impact with gender perspective

Of the total sample of primary survey, 6 percent households were female-headed households. And of these, over 44 percent owned an Android/smart phone. This shows that these women realise the importance and the worth of information. Almost 70 percent of these women headed households have an average annual income of Rs. 2.5 lakh to Rs. 4 lakh. Besides, while the remaining 94 percent of the households are male-headed households, women still play an extremely important role.

The job of women in agricultural households range from sowing, nursery management, transplanting, weeding, hoeing, grass cutting, irrigation, fertilizer application, plant protection, separation of seeds from fibre/chaffing, harvesting, winnowing, storing etc. Women in families owning livestock perform jobs of cleaning sheds, bathing cattle, milking, fodder gathering, collecting farmyard manure, preparing dung cakes, processing milk and preparing products like curd, buttermilk, whey, ghee and other products.

In the fisheries sector, women play a supporting role on land to the sea going person. Assistance from women relieves fishermen of concerns related to finance, supplies sourcing, crew/staff management and marketing. Women take care of customer base, enhance it, keep track of prices so as to mark up or mark down, nets and other fishing assets. Women also have to execute the domestic chores of running family and bring up kids and taking care of the elders.

Every woman from a fishing household wants to know the ocean state forecast provided by INCOIS on a daily basis as they want to be assured that their men are safe at sea. They call INCOIS almost every day by practice, even though they receive the voice message on weather at sea from RFIS. Irrespective of whether women have ownership of the land or not, they have a huge impact on the sources of livelihood and the family. This is how these agriculture, livestock or fisheries households thrive and grow.

Realising the importance of women in different economic activities and also realizing the importance of weather predictions to women, the economic benefit accruing to the womenfolk is also estimated in this study. For this, the "Periodic Labour-force Survey" (PLFS) conducted by National Sample Survey Office (NSSO)[15] for the year 2017-18 has been analysed to arrive at the proportion of women employed in the three economic activities of farming, livestock rearing and fishing. These shares are 26.9 percent among farmers, 48.5 percent among livestock rearing community and 4.9 percent among fishing community.

Assuming that the economic value of weather predictions is as useful for a man as it is to woman, the economic gain realized by women is derived by applying these ratios on the economic benefits accrued to farmers, livestock-owners and fisherfolk, respectively. The hence derived estimated benefits realized by the women works out to be Rs. 13,447 crore, which is 26.6 percent of the total benefit.

IV.5. Concluding remarks and Way Forward

This study finds that the improvements in weather predictions due to Monsoon Mission have resulted in a massive economic gain in the income of agricultural households belonging to rain-fed areas and fishing households living in coastal areas. These economic gains not just include the increase in income due to appropriate actions taken like modifications adopted in agricultural practices based on weather advisories but also include

[15]Government of India, "Periodic Labour Force Survey, 2017-18", National Sample Survey Office (NSSO), New Delhi.

the gains resulting from the avoidance of losses which could have burdened them, had there been no advisories.

In monetary terms, the investment equivalent to Rs. 1000 crore in setting up NMM and HPC facilities have resulted in an approximate gain of Rs. 50,000 crore.

This gain refers to the direct economic benefits accrued to the stakeholder-households, in monetary terms. But accurate prediction of cyclones and other weather calamities in timely manner also saves a lot of human lives and physical disabilities. Estimation of economic value of such non-economic benefits was out of scope of this report. But it is of significant importance to elaborate on value of non-economic benefits realized because of number of human lives saved as well as number of human disabilities averted as a result of accurate weather prediction. Future scope of similar study may include estimation of economic value of averted deaths and years lost to disabilities which are valued using value of statistical life and disability adjusted life years approaches. Only recent cyclones such as Fani, Amphan and Nisarga would have collectively caused tens of thousands of casualties had they not been accurately predicted using high resolution models run on HPCs. If all the lives and disabilities averted are converted into monetary value, this would add another thousands of crore rupees to the country's GDP. Hence, it will be a value addition to design future studies in this light.

Annexure I – Questionnaires for Farmers, Livestock owners, Fisher folk

Monsoon Mission Study

Schedule for Farmers

Name of surveyor

Demographics

Please provide the following details about the respondent

a	**State Name**	
b	**District Name**	
c	**Sub District Name**	
d	**Village Name**	
e	**Name of the respondent**	
f	**Mobile No. of the respondent**	
g	**Age of the respondent**	
h	**Gender of the respondent**	1 - Male 2 - Female
i	**Family size (no. of persons)**	

1. **Livelihood type major - choose multiple if applicable**
   1 – Agriculture, 2 – Fisheries, 3 – Livestock

2. **Education**
   1 – Illiterate, 2 – Below Primary, 3 – Primary, 4 – Middle,
   5 – Secondary, 6 – Hr. Sec, 7 – Diploma, College & above

3. **What is your ANNUAL expenses incurred for family?**
   In INR ☐☐ ☐☐ ☐☐☐

4. **What is your ANNUAL family income including all the earning members of your family?**
   In INR ☐☐ ☐☐ ☐☐☐

5. How much agricultural land do you have in ACRES?

Land category	Land area	Unit of land
a) Total land owned		
b) Rain fed land (owned)		
c) Irrigated land (owned)		
d) Land leased in (not owned)		
e) Land leased out		

6. Which are your major crops during Kharif and Rabi?

Kharif Crops	Rabi Crops
1	1
2	2
3	3

7. Which are your five major livestock including poultry?

Livestock
1
2
3
4
5

8. Are you having mobile phone?
1 – Yes 2 – No

9. If 'Yes', type of phone:
1 – Feature Phone 2 – Smart Phone

10. Which of the following have you used over the past 6 years to get Weather information? Read out options. Mention multiple, if applicable

1 – Television,
2 – Radio,
3 – Newspapers,
4 – Voice SMS,
5 – WhatsApp,
6 – Reliance Foundation Toll Free Helpline Number,
7 – JioChat,
8 – Social Media (Twitter/Facebook..)
9 – SMS through Kisan Portal, GoI
10 – SMS through Reliance Foundation
11 – Email / Internet
12 – Meghdoot App Launched by MoES
13 – Friends / Relatives
14 – Agricultural Universities / ICAR Institutes / IITs
15 – State Agriculture Department

11. Do you share the weather information with others?
1 – Yes, 2 – No

12. I will ready out some communication technologies. Of these, please tell me which ones you prefer the most for getting weather information and advisories? (Order response in terms of preference)

Technology	Rank (1 to 10)
Voice SMS	
Helpline	
Television	
Radio	
Newspaper	
Internet	
WhatsApp	
Jio Chat	
SMS through Kisan Portal, GoI	
Meghdoot App Launched by MoES	

13. Based on the weather or climate forecast, have you taken decision on the following farming practices?

Response	Yes	No
Crop selection/ Seed selection /Variety Selection		
Time of Sowing		
Irrigation		
Crop growth management practices		
Application of fertilizer or pesticide		
Early Harvesting / Late Harvesting		
Contingency planning / management (Multi Cropping, Protective Measures, etc)		

14. How frequently you were using / do you use Weather information?

	Twice a week	Once a week	Once in two week	Once a month	Seasonally
Currently					
Before 2015					

15. Were you affected by any natural calamity such as drought, flood, cyclone, hailstorm, wind in the past 2 years?
1 – Yes, 2 – No

16. How many times you have received correct information on natural calamities in the last 5 years?
1- Almost Every Time 2 – Occasionally 3 – Rarely 4 - Never

17. Has weather / climate forecast helped you in reducing the losses occurred due to natural calamities?
1 – Yes 2 – No 3 – No Opinion / Can't Say

18. What are the major parameters that you consider while planning the crop selection or cultivation? (Read out the options and request to rank on a scale of 5. Rank 5 being very important while 1 being not important)

Sl No.	Parameters	Rating
1	Factors such as rainfall, drought, etc.	
2	Factors such as pests and diseases	
3	Cost of cultivation	
4	Access to farm input	
5	Marketability / Market price	
6	Profitability	

19. How important is getting rain information for you to use in agriculture on the following parameters?

Sl No.	Parameters	Code: 1- Very important 2- Less important 3- Not important 4- Don't know/Can't say
1	Decision making in risk / return, crop selection, time of sowing	
2	Averting loss due to pest, disease, etc	
3	Increasing the income	
4	Deciding intercultural operations	

20. How many days prior do you need rain information and advisory to use it on the following parameters in agriculture?

	Questions	Frequency 1 – One day in advance 2 – Before 3-4 days 3 – Before a week 4 – Before onset of a season 5 – Not applicable / Cant say
a	Planning of **Sowing/Planting**	
b	Planning of **Irrigation**	
c	Planning of **Intercultural Operations on Soil such as Fertilizer, Pesticides, Mulching**	
d	Planning of **Transplanting**	
e	**Pest and Disease to Care during growth phase of your crop**	
f	Planning of **Harvesting**	
g	Planning **Post-Harvest Operations**	

21. Do you get information on any of the following weather parameters?

1 – Rainfall 2 – Temperature 3 – Humidity
4 – Wind speed & direction 5 – Cloud

22. Which weather parameters are important for crop cultivation?

1 – Rainfall 2 – Temperature 3 – Humidity
4 – Wind speed & direction 5 – Cloud

23. What are the other weather / climate variables you wish to have for efficient management of your crops?

Please specify _____

24. How relevant the weather or climate forecast advisories are for day to day farm operations?

1. Very relevant
2. Somewhat relevant
3. Not relevant
4. Don't know / Can't say

25. Please furnish the following information on forecasts related to temperature/ chances of rain/ cloud coverage/ wind

Sl No	25a. By continuously using forecasts related to temperature, rain, cloud coverage and wind, have you changed the following? (Read out options) Tick responses		(ASK FOR ONLY SELECTED ONES) 25b. Were you able to reduce losses by changing it? (Yes – 1 | No – 2)		25c. Have this increased your income? (Yes – 1 | No – 2)	
a.	Changed variety/breed		1	2	1	2
b.	Arranged for storage of harvest		1	2	1	2
c.	Early/delayed harvesting		1	2	1	2
d.	Changed crop		1	2	1	2
e.	Early/delayed sowing		1	2	1	2
f.	Changed schedule of ploughing/land preparation		1	2	1	2
g.	Changed pesticide application schedule		1	2	1	2
h.	Changed fertilizer application schedule		1	2	1	2
i.	Changed scheduled irrigation		1	2	1	2

Monsoon Mission Study

Schedule for Livestock Owners

Name of surveyor

Demographics

Please provide the following details about the respondent

a	**State Name**	
b	**District Name**	
c	**Sub District Name**	
d	**Village Name**	
e	**Name of the respondent**	
f	**Mobile No. of the respondent**	
g	**Age of the respondent**	
h	**Gender of the respondent**	1 - Male 2 - Female
i	**Family size (no. of persons)**	

1. **Livelihood type major - choose multiple if applicable**
   1 – Agriculture, 2 – Fisheries, 3 – Livestock

2. **Education**
   1 – Illiterate, 2 – Below Primary, 3 – Primary, 4 – Middle,
   5 – Secondary, 6 – Hr. Sec, 7 – Diploma, College & above

3. **What is your ANNUAL expenses incurred for family?**
   In INR ☐☐ ☐☐ ☐☐☐

4. **What is your ANNUAL family income including all the earning members of your family?**
   In INR ☐☐ ☐☐ ☐☐☐

5. **How much agricultural land do you have in ACRES**?

Land category	Land area	Unit of land
a) Total land owned		
b) Rain fed land (owned)		
c) Irrigated land (owned)		
d) Land leased in (not owned)		
e) Land leased out		

6. Which are your five major livestock including poultry?

Livestock
1
2
3
4
5

7. Are you having mobile phone?
1 – Yes 2 – No

8. If 'Yes', type of phone:
1 – Feature Phone 2 – Smart Phone

9. Which of the following have you used over the past 6 years to get Weather information? Read out options. Mention multiple, if applicable

1 – Television,

2 – Radio,

3 – Newspapers,

4 – Voice SMS,

5 – WhatsApp,

6 – Reliance Foundation Toll Free Helpline Number,

7 – JioChat,

8 – Social Media (Twitter/Facebook)

9 – SMS through Kisan Portal, GoI

10 – SMS through Reliance Foundation

11 – Email / Internet

12 – Meghdoot App Launched by MoES

13 – Friends / Relatives

14 – Agricultural Universities / ICAR Institutes / IITs

15 – State Agriculture Department

10. Do you share the weather information with others?
1 – Yes, 2 – No

11. I will read out some communication technologies. Of these, please tell me which ones you prefer the most for getting weather information and advisories? (Order response in terms of preference)

Technology	**Rank (1 to 10)**
Voice SMS	
Helpline	
Television	
Radio	
Newspaper	
Internet	
WhatsApp	
Jio Chat	
SMS through Kisan Portal, GoI	
Meghdoot App Launched by MoES	

12. Based on the weather or climate forecast, have you taken decision on the following livestock management practices?

Response	**Yes**	**No**
Modification of Shed / Shelter		
Vaccination against seasonal disease		
Fodder Management (fodder stocking, late grazing, etc)		
Other (specify)		

13. How frequently you were using / do you use Weather information?

	Twice a week	Once a week	Once in two week	Once a month	Seasonally
Currently					
Before 2015					

14. Were you affected by any natural calamity such as drought, flood, cyclone, hailstorm, wind in the past 2 years?
1 – Yes, 2 – No

15. How many times you have received correct information on natural calamities in the last 5 years?

1- Almost Every Time 2 – Occasionally 3 – Rarely 4 - Never

16. Has weather / climate forecast helped you in reducing the losses occurred due to natural calamities?

1 – Yes 2 – No 3 – No Opinion / Can't Say

17. What are the major parameters that you consider while planning livestock rearing? (Read out the options and request to rank on a scale of 5. Rank 5 being very important while 1 being Not important)

Sl No.	Parameters	Rating
1	Factors such as rainfall, drought, etc.	
2	Factors such as diseases management and veterinary facilities	
3	Investment	
4	Feeding and fodder management	
5	Marketability / Market price	
6	Profitability	

18. How important is getting rain information for you to use in Livestock Rearing on the following parameters?

Sl No.	Parameters	Code: 1- Very important 2- Less important 3- Not important 4- Don't know/Can't say
1	Averting productivity loss due to disease	
2	Averting loss due to disease	
3	Shed / shelter management	
4	Fodder management / Mineral mixture	
5	Disease management	

19. Do you get information on any of the following weather parameters?

1 – Rainfall 2 – Temperature 3 – Humidity 4 – Wind speed & direction 5 – Cloud

20. Which weather parameters are important for Livestock Management?

1 – Rainfall 2 – Temperature 3 – Humidity 4 – Wind speed & direction 5 – Cloud

21. What are the other weather / climate variables you wish to have for efficient Livestock Management? Please specify _____

22. How relevant the weather or climate forecast advisories are for day to day Livestock Management?

1. Very relevant, 2 - Somewhat relevant, 3 - Not relevant, 4 - Don't know / Can't say

Monsoon Mission Study

Schedule for Fisher-folk

RFIS Employee Name

Demographics

Please provide the following details about the respondent

State Name	
District Name	
Sub District Name	
Village Name	
Name of the respondent	
Mobile No. of the respondent	
Age of the respondent	
Gender of the respondent	1 - Male 2 - Female
Family size (no. of persons)	

1. **Livelihood type major - choose multiple if applicable**

   1 – Agriculture, 2 – Fisheries, 3 – Livestock

2. **Education**

   1 – Illiterate, 2 – Below Primary, 3 – Primary, 4 – Middle, 5 – Secondary,
   6 – Hr. Sec, 7 – College & above

3. **What is your ANNUAL EXPENSES incurred for family?**

   In INR ☐☐ ☐☐ ☐☐☐

4. **What is your ANNUAL FAMILY INCOME including all the earning members of your family?**

   In INR ☐☐ ☐☐ ☐☐☐

5. Which of the following have you used over the past 6 years to get Weather information? Mention multiple, if applicable

1 –Television
2 – Radio
3 – Newspapers
4 – Voice SMS
5 – WhatsApp
6 – Reliance Foundation Toll Free Helpline
7 – Jio Chat
8 – Social Media (Twitter/Facebook..)
9 – SMS through Kisan Portal, GoI
10 – SMS through Reliance Foundation
11 – Email / Internet
12 – Friends / Relatives
13 – Reliance Foundation Machli Application
14 – Mobile Application from other organisations

6. Do you share the weather information with others?
1 – Yes, 2 – No

7. I will read out some technologies. Of these, please tell me which ones you prefer the most for getting weather forecast? (Order response in terms of preference)

Technology	Rank (1 to 8)
Voice SMS	
Helpline	
Television	
Radio	
Newspaper	
Internet	
WhatsApp	
JIO Chat	

8. What is the accuracy level of weather forecast and cyclone warnings that you received BEFORE 2015?

1 – Always accurate 2 – Sometimes accurate 3 – Never accurate
4 – Don't know / can't say

9. What is the accuracy level of weather forecast and cyclone warnings that you received AFTER 2015?

1 – Always accurate 2 – Sometimes accurate 3 – Never accurate
4 – Don't know / can't say

10. How frequently you were using / do you use Weather and Cyclone warnings?

Response	Daily	Twice a week	Once a week	Once a month	Seasonally
Currently					
Before 2015					

11. Were you affected by any natural calamity such as flood, cyclone etc. in the past 2 years?

1 – Yes, 2 – No

12. Did you get the information about the LATEST calamity (flood, cyclone, etc) on time?

1 – Yes, 2 – No

13. Were you able to minimize the loss of assets/ livestock etc. caused by the LATEST calamity (flood, cyclone, etc)?

1 – Yes, 2 – No

14. How important is getting high wave, high wind, cyclonic warning, etc for you to use it in fishing activities on the following parameters?

Sl No.	**Parameters**	**Code:** 1- Very important 2- Less important 3- Not important 4- Don't know/Can't say
1	Averting loss	
2	Increasing the income	
3	Decision making in venturing into sea	
4	Reducing loss from empty trip and input cost	

15. How many days prior do you need high wave, high wind, cyclonic warning, etc to use in fishing?

Days prior. ☐

16. How frequently you need high wave, high wind, cyclonic warning, etc to use in fishing?

1 - Several times a day
2 - Every 6 hours
3 - Daily

17. Whether you follow the OSF advisories to decide on venturing into sea for fishing?

1 – Yes, always, 2 – Yes, sometime, 3 – Not at all

18. IF YES - In a year, how many empty trips you would have avoided based on the OSF advisories/ other calamity alerts?

Empty trips. ☐

19. What is the approximate operational cost per trip you have avoided by following OSF advisories/ other calamity alerts?

In INR ☐☐ ☐☐☐

20. In the last one year, how many PFZ advisories you received?

No of PFZ advisories. ☐

20a. In the last one year, how many trips you made using PFZ advisories?

No of trips. ☐

21. Out of the trips made based on PFZ advisories, how many trips recorded additional fish catch?

No of trips. ☐

22. What is the average additional income you received per trip made based on PFZ advisories?

In INR ☐☐ ☐☐ ☐☐☐

23. What type of boat you use for fishing?

1 – Mechanised (trawler, gillnetter, pole & liners)
2 – Motorised (FRB with outboard motors)
3 – Non-motorised (catamaran, canoes)

Annexure II – Sample size by districts

Table A1: District-wise number of farmers interviewed

State	District	Sample farmers
Andhra Pradesh	Ananthapur	42
Andhra Pradesh	Chittoor	21
Andhra Pradesh	Cuddapah	34
Andhra Pradesh	East Godavari	23
Andhra Pradesh	Guntur	13
Andhra Pradesh	Krishna	15
Andhra Pradesh	Kurnool	36
Andhra Pradesh	Nellore	23
Andhra Pradesh	Prakasam	28
Andhra Pradesh	Srikakulam	19
Andhra Pradesh	Visakhapatnam	15
Andhra Pradesh	Vizianagaram	24
Andhra Pradesh	West Godavari	36
Gujarat	Amreli	28
Gujarat	Arvalli	35
Gujarat	Banaskantha	35
Gujarat	Bharuch	35
Gujarat	Devbhoomi Dwarka	35
Gujarat	Girsomnath	27
Gujarat	Junagadh	36
Gujarat	Kutch	35
Gujarat	Navsari	34
Gujarat	Patan	38
Gujarat	Porbandar	22
Gujarat	Rajkot	35
Gujarat	Sabarkantha	32
Gujarat	Surendranagar	33
Gujarat	Valsad	34
Karnataka	Dakshina Kannada	26
Karnataka	Shimoga	49
Karnataka	Udupi	26

State	District	Sample farmers
Kerala	Alappuzha	16
Kerala	Ernakulam	25
Kerala	Kollam	10
Kerala	Kozhikode	24
Kerala	Malappuram	30
Kerala	Thiruvananthapuram	11
Kerala	Wayanad	35
Madhya Pradesh	Bhopal	29
Madhya Pradesh	Chhindwara	39
Madhya Pradesh	Dindori	40
Madhya Pradesh	Indore	38
Madhya Pradesh	Jabalpur	30
Madhya Pradesh	Mandla	33
Madhya Pradesh	Panna	30
Madhya Pradesh	Raisen	33
Madhya Pradesh	Rewa	31
Madhya Pradesh	Satna	27
Madhya Pradesh	Sehore	40
Madhya Pradesh	Seoni	34
Madhya Pradesh	Shajapur	34
Madhya Pradesh	Umaria	33
Maharashtra	Akola	50
Maharashtra	Amravati	50
Maharashtra	Bhandara	49
Maharashtra	Buldhana	30
Maharashtra	Chandrapur	47
Maharashtra	Gondia	50
Maharashtra	Hingoli	50
Maharashtra	Jalana	46
Maharashtra	Kolhapur	50
Maharashtra	Latur	48
Maharashtra	Nagpur	50
Maharashtra	Nanded	49

State	District	Sample farmers
Maharashtra	Parbhani	27
Maharashtra	Ratnagiri	38
Maharashtra	Sangli	50
Maharashtra	Satara	48
Maharashtra	Sindhudurg	26
Maharashtra	Wardha	50
Maharashtra	Washim	50
Maharashtra	Yavatmal	48
Odisha	Angul	35
Odisha	Baleshwar	20
Odisha	Bargarh	34
Odisha	Bhadrak	20
Odisha	Gajapati	33
Odisha	Ganjam	25
Odisha	Jagatsinghpur	15
Odisha	Kalahandi	24
Odisha	Kendrapara	16
Odisha	Mayurbhanj	50
Odisha	Nayagarh	46
Odisha	Nuapada	51
Odisha	Puri	26
Odisha	Sambalpur	35
Odisha	Subarnapur	33
Rajasthan	Bikaner	21
Rajasthan	Jhalawar	25
Rajasthan	Jodhpur	24
Rajasthan	Udaipur	29
Tamil Nadu	Ariyalur	35
Tamil Nadu	Cuddalore	23
Tamil Nadu	Dindigul	19
Tamil Nadu	Kancheepuram	40
Tamil Nadu	Kanyakumari	15
Tamil Nadu	Karur	41

State	District	Sample farmers
Tamil Nadu	Madurai	32
Tamil Nadu	Nagapattinam	25
Tamil Nadu	Namakkal	35
Tamil Nadu	Perambalur	55
Tamil Nadu	Pudukkottai	35
Tamil Nadu	Ramanathapuram	20
Tamil Nadu	Salem	30
Tamil Nadu	Sivaganga	37
Tamil Nadu	Thanjavur	35
Tamil Nadu	Theni	26
Tamil Nadu	Thiruvarur	47
Tamil Nadu	Tiruchirappalli	41
Tamil Nadu	Tirunelveli	14
Tamil Nadu	Tiruvallur	46
Tamil Nadu	Tiruvannamalai	24
Tamil Nadu	Tuticorin	13
Tamil Nadu	Viluppuram	27
Tamil Nadu	Virudhunagar	42
Telangana	Kamareddy	27
Telangana	Khammam	35
West Bengal	Bankura	35
West Bengal	Nadia	32
West Bengal	North 24 Parganas	35
West Bengal	South 24 Parganas	30
ALL		3,965

Source: NCAER-RFIS Survey 2019

Table A2: District-wise number of livestock owners interviewed

State	District	Sample livestock owners
Andhra Pradesh	Ananthapur	14
Andhra Pradesh	Chittoor	27
Andhra Pradesh	Cuddapah	15
Andhra Pradesh	East Godavari	22
Andhra Pradesh	Guntur	14
Andhra Pradesh	Krishna	11
Andhra Pradesh	Kurnool	13
Andhra Pradesh	Nellore	14
Andhra Pradesh	Prakasam	9
Andhra Pradesh	Srikakulam	10
Andhra Pradesh	Visakhapatnam	18
Andhra Pradesh	Vizianagaram	6
Andhra Pradesh	West Godavari	15
Gujarat	Amreli	20
Gujarat	Arvalli	15
Gujarat	Banaskantha	14
Gujarat	Bharuch	15
Gujarat	Devbhoomi Dwarka	15
Gujarat	Girsomnath	5
Gujarat	Junagadh	15
Gujarat	Kutch	15
Gujarat	Navsari	15
Gujarat	Patan	16
Gujarat	Porbandar	4
Gujarat	Rajkot	16
Gujarat	Sabarkantha	15
Gujarat	Surendranagar	17
Gujarat	Valsad	15
Kerala	Alappuzha	12
Kerala	Ernakulam	1
Kerala	Kollam	11
Kerala	Kozhikode	3
Kerala	Malappuram	21
Kerala	Thiruvananthapuram	12
Kerala	Wayanad	15
Madhya Pradesh	Bhopal	23

State	District	Sample livestock owners
Madhya Pradesh	Chhindwara	16
Madhya Pradesh	Dindori	9
Madhya Pradesh	Indore	15
Madhya Pradesh	Jabalpur	20
Madhya Pradesh	Mandla	15
Madhya Pradesh	Panna	18
Madhya Pradesh	Raisen	17
Madhya Pradesh	Rewa	20
Madhya Pradesh	Satna	23
Madhya Pradesh	Sehore	14
Madhya Pradesh	Seoni	13
Madhya Pradesh	Shajapur	14
Madhya Pradesh	Umaria	19
Maharashtra	Buldhana	19
Maharashtra	Parbhani	25
Odisha	Angul	15
Odisha	Baleshwar	5
Odisha	Bargarh	15
Odisha	Bhadrak	5
Odisha	Gajapati	14
Odisha	Ganjam	3
Odisha	Jagatsinghpur	10
Odisha	Kalahandi	24
Odisha	Kendrapara	9
Odisha	Nayagarh	20
Odisha	Sambalpur	15
Odisha	Subarnapur	16
Rajasthan	Bikaner	22
Rajasthan	Jhalawar	25
Rajasthan	Jodhpur	24
Rajasthan	Udaipur	17
Tamil Nadu	Ariyalur	16
Tamil Nadu	Cuddalore	3
Tamil Nadu	Dindigul	31
Tamil Nadu	Kancheepuram	3
Tamil Nadu	Kanyakumari	10
Tamil Nadu	Madurai	19
Tamil Nadu	Namakkal	15

State	District	Sample livestock owners
Tamil Nadu	Pudukkottai	15
Tamil Nadu	Ramanathapuram	5
Tamil Nadu	Salem	20
Tamil Nadu	Sivaganga	13
Tamil Nadu	Thanjavur	15
Tamil Nadu	Theni	25
Tamil Nadu	Tirunelveli	12
Tamil Nadu	Tiruvallur	5
Tamil Nadu	Tiruvannamalai	27
Tamil Nadu	Tuticorin	12
Tamil Nadu	Viluppuram	25
Tamil Nadu	Virudhunagar	8
Telangana	Kamareddy	22
Telangana	Khammam	13
West Bengal	Bankura	14
West Bengal	Nadia	19
West Bengal	North 24 Parganas	15
West Bengal	South 24 Parganas	20
ALL		1,376

Source: NCAER-RFIS Survey 2019

Table A3: District-wise number of fishermen surveyed

State	District	Sample fishermen
Maharashtra	Ratnagiri	22
Gujarat	Girsomnath	20
Kerala	Thiruvananthapuram	25
Gujarat	Porbandar	20
Karnataka	Dakshina Kannada	25
Odisha	Jagatsinghpur	26
Karnataka	Udupi	22
Tamil Nadu	Kancheepuram	25
Kerala	Kozhikode	25
Odisha	Kendrapara	25
Kerala	Kollam	31
Maharashtra	Sindhudurg	29
Tamil Nadu	Tirunelveli	24
Tamil Nadu	Ramanathapuram	25
Odisha	Bhadrak	25
Tamil Nadu	Kanyakumari	25
Andhra Pradesh	Krishna	24
Andhra Pradesh	Guntur	24
Andhra Pradesh	East Godavari	10
Andhra Pradesh	West Godavari	20
Tamil Nadu	Cuddalore	27
Odisha	Puri	24
Kerala	Alappuzha	22
Odisha	Baleshwar	25
Tamil Nadu	Tuticorin	25
Kerala	Ernakulam	25
Tamil Nadu	Nagapattinam	25

State	District	Sample fishermen
Andhra Pradesh	Visakhapatnam	18
Andhra Pradesh	Nellore	16
Andhra Pradesh	Prakasam	13
Odisha	Ganjam	22
Andhra Pradesh	Vizianagaram	20
Odisha	Gajapati	3
Andhra Pradesh	Srikakulam	20
ALL		757

Source: NCAER-RFIS Survey 2019

Annexure III– Values of Production of food grains

Table A4: Production of food grains in rain-fed and irrigated districts (2011-17)

(in lakh tonnes)

			Bajra	Barley	Jowar	Maize	Other Cereals	Ragi	Rice	Small millets	Wheat	Total
IRRIGATED (DPAP/DDP non-eligible	Pre-NMM	2011	85.8	12.2	23.2	247.6	0.9	17.5	1469.9	2.2	944.7	2804.1
		2012	69.7	13.4	19.1	249.6	0.5	14.3	1492.0	1.9	915.2	2775.7
		2013	76.4	13.3	28.0	284.7	0.4	20.1	1512.0	2.1	933.6	2870.7
		2014	72.7	11.1	33.7	282.5	0.0	18.3	1571.2	2.3	758.6	2750.3
	Post NMM	2015	60.8	9.8	22.5	256.0	0.1	17.7	1380.5	2.4	749.0	2498.9
		2016	60.5	10.4	16.4	289.6	0.6	8.7	1546.5	1.4	718.0	2652.0
		2017	60.6	10.5	27.4	341.2	0.3	23.7	1517.8	1.4	712.0	2695.0
RAINFED (DPAP/DDP eligible	Pre NMM	2011	56.4	3.8	77.8	143.6	0.2	14.4	203.5	1.8	85.7	587.1
		2012	29.3	4.8	72.2	142.2	0.2	11.2	219.3	1.8	85.4	566.4
		2013	38.2	4.8	82.1	191.6	0.1	17.0	250.1	2.4	96.1	682.3
		2014	33.4	4.3	64.1	151.9	0.0	18.9	234.6	1.6	91.0	599.9
	Post NMM	2015	21.9	3.5	42.4	126.9	0.0	15.4	160.1	2.6	81.3	454.2
		2016	32.2	4.4	66.8	134.6	1.4	7.9	220.9	0.9	74.2	543.3
		2017	29.9	3.7	63.9	169.4	0.6	17.8	173.9	0.8	68.0	528.0

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