NCAER

Economic Benefits of Dynamic Weather and Ocean Information and Advisory Services in India and Cost and Pricing of Customized Products and Services of ESSO-NCMRWF & ESSO-INCOIS

National Council of Applied Economic Research

Economic Benefits of Dynamic Weather and Ocean Information and Advisory Services in India

and

Cost and Pricing of Customized Products and Services of ESSO-NCMRWF & ESSO-INCOIS

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Preface

The National Council of Applied Economic Research has had a productive knowledge and research partnership since 2010 with the Ministry of Earth Sciences (MoES) in the Government of India. MoES is mandated to provide the nation with best-in-class services in forecasting monsoons and other weather parameters, ocean states, earthquakes, tsunamis and other phenomena related to earth systems through well integrated programmes.

The Ministry recently requested NCAER to estimate the economic benefits of dynamic weather and ocean state forecasts and the resulting advisories provided to users. NCAER was also asked to prepare costing and pricing approaches and the development of associated templates for the work of the Earth System Science Organization-National Centre for Medium Range Weather Forecasting (ESSO-NCMRWF) in Noida and for the Hyderabad-based Earth System ScienceOrganization Indian National Centre for Ocean Information Services (ESSO-INCOIS), both agencies functioning under MoES. These are specialised scientific agencies that ESSO-NCMRWF seeks to develop advanced numerical weather prediction systems of increasing reliability and accuracy for India and neighbouring regions. ESSO-INCOIS seeks to provide ocean information and advisory services to citizens, industry, utilities, government, including the defence services such as the Indian Navy and the Coast Guard, and the scientific community, including as an early warning system for tsunamis and storm surges, through sustained ocean observations and systematic, focused research.

This report, the third in the series of NCAER's work with MoES, consists of two parts. The first part estimates the potential economic benefits of ESSO-NCMRWF dynamic weather forecasts (coordinated with the Indian Meteorological Department) for the farming community, ESSO-INCOIS's ocean state forecasts to different users for strategic purposes, its Potential Fishing Zones advisories to marine fishing communities, and its "No Tsunami Threat" advisories. The methodology for estimation of benefits is a unique combination of unit level analysis of agricultural households using data from the National Sample Survey, customised surveys of farming and fishing communities, and interviews with strategic users of these forecasts. Using an innovative approach that departs from convention, the economic benefits of providing ocean state and 'No Tsunami Threat' forecasts were estimated by analysing the expenditure saved on activities that were cancelled due to advance availability of these forecasts. The second major part of this NCAER Report develops costing and pricing approaches and templates for the development of NCMRWF and ESSO-INCOIS products and services.

NCAER wishes to express its gratitude to Dr Parvinder Maini (MoES), Dr Praveen Kumar and Mr Gopal Iyengar (ESSO-NCMRWF), and Dr Balakrishnan T M Nair, Dr Hari Kumar, and Dr Pattabhi Rama Rao E (ESSO-INCOIS) for their unstinting assistance and willingness to share information and insights during the course of this study. We would also like to appreciate Mr Senthil Kumaran S, Dr Gangavidya Narayanan and their field teams from Reliance Foundation Information Services for collating the customised survey data. Finally I am very grateful to Dr D Jagannathan, external costing consultant, for preparing the chapter on costing and pricing.

Most importantly, I would like to thank the NCAER team that did this work for their important contributions to estimating the potential economic benefits of dynamic weather and ocean state forecasts. The NCAER team comprised our Principal Investigator and team leader, R Venkatesan, and co-Principal Investigator, Dr Poonam Munjal, team members Amit Sharma and Chavi Meattle, and Swati Kandwal, project assistant.

I am particularly grateful to Mr R Venkatesan for his continuous guidance of the ongoing work on technology and ICT at NCAER, a work that I suspect will grow as India deepens its involvement with digital technology at levels of society, industry, and government.

Shekhar Shah
Director-General

August 13, 2015

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Abbreviations

A	
AAS	Agricultural Advisory Service
AGCM	Atmospheric General Circulation Model
AMFUs	Agro-Meteorological Field Units
ASG	Advisory Services and Satellite Oceanography Group
AVHRR	Advanced Very High Resolution Radiometer
B	
BARC	Bhabha Atomic Research Centre
BCM	Billion Cubic Metre
BPL	Below Poverty Level
BRIC	Brazil, Russia, India and China
C	
CER	Certified Emission Reduction
CDMA	Code Division Multiple Access
CMFRI	Central Marine Fisheries Research Institute
CSO	Central Statistical Organisation
D	
DMG	Data Management Group
DRDO	Defence Research and Development Organization
E	
ECMWF	European Centre for Medium Range Weather Forecasts
EDB	Electronic Display Board
EPW	Economic and Political Weekly
Estd.	Estimated
F	
FHs	Fishing Harbours
FLCs	Fish Landing Centres
G	
GDP	Gross Domestic Product
GIS	Geographic Information System
GPS	Global Positioning System
GSM	Global System for Mobile
GVA	Gross Value Added
H	
Ha	Hectare
HPC	High Performance Computing
I	
ICG	Indian Coast Guard

ICT	Information And Communications Technology
IMD	India Meteorological Department
ESSO-INCOIS	Indian National Centre for Ocean Information Services
ISG	Information Services and Ocean Sciences Group
ISRO	Indian Space Research Organisation
ITEWC	Indian Tsunami Early Warning Centre
K	
KWH	kilowatt-hour
M	
METOC	Meteorology and Oceanography
MMT	Million metric tonne
MODIS	Moderate Resolution Imaging Spectroradiometer
MOSPI	Ministry of Statistics and Programme Implementation
MPCE	Monthly Per Capita Expenditure
MSSRF	M.S. Swaminathan Research Foundation
MW	Mega Watt
N	
NCAER	National Council of Applied Economic Research
NCEP	National Centers for Environmental Prediction
ESSO-NCMRWF	National Centre for Medium Range Weather Forecasting
NDRF	National Disaster Resource Fund
NGO	Non-Governmental Organization
NIOT	National Institute of Ocean Technology
NOAA	National Oceanic and Atmospheric Administration
NODPAC	Naval Operations Data Processing & Analysing Centre
NSSO	National Sample Survey Organisation
O	
OBC	Other Backward Class
ONGC	Oil and Natural Gas Corporation
OOSA	Online Oil Spill Advisory
OSF	Ocean State Forecast
P	
PFZ	Potential Fishing Zone
PPM	Perfect Prognostic Method
PV	Present Value
R	
R&D	Research and Development
RFIS	Reliance Foundation Information Services
RIMES	Regional Integrated Multi-Hazard Early Warning System
RS	Remote Sensing

S	
SC	Scheduled Caste
SI	Statistical Interpretation
SST	Sea Surface Temperature
ST	Scheduled Tribe
U	
UTs	Union Territories
V	
VKCs	Village Knowledge Centres
VRCs	Village Resource Centres
W	
WMO	World Meteorological Organization
Y	
Y-o-Y	Year on Year

Executive Summary

Executive Summary

Scope of the Study

- The National Centre for Medium Range Weather Forecasting (ESSO-NCMRWF) was set up in 1988 in the aftermath of the extreme climatic events in northwest India during the winter of 1983-84 when the Rabi crops were being harvested. ESSO-NCMRWF's achievements over the 26 years of its existence shows that it has been serving the mission of generating dynamic weather prediction using in-house R&D, successfully; however, an empirical examination of the following is needed:

    - Whether ESSO-NCMRWF has been continuously able to improve its weather prediction system with high accuracy, from the perceptions of main stakeholders— farmers— that the ESSO-NCMRWF is serving in association with IMD.
    - Whether the coupled ocean atmospheric modelling is successful from the perspective of the main stakeholder—the fishing community—that the ESSO-NCMRWF is serving in association with ESSO-INCOIS.
    - What are the net economic benefits of serving the above main stakeholders?
    - What would be the future direction for ESSO-NCMRWF? Would it be to serve renewable energy generating power utilities with location specific forecasts on wind speed, direction and cloud cover to enable them to supply a greater share of energy to grid?

    This report attempts to answer the aforementioned key questions.

- The Indian National Centre for Ocean Information Services (ESSO-INCOIS) was set up in 1999 under the Ministry of Earth Sciences (MoES) to provide ocean information and advisory services to the Indian Navy, the Indian Coast Guard, Ports, Maritime Boards, offshore oil and gas exploration industries and merchant shipping industries. It also provides 'Tsunami Advisories' as well as identification of potential fishing zones. Till date there has been no quantification of the net economic benefits of providing such services to its users. This reports fulfils this void through in-depth interviews and discussion with these major stakeholders.

- The report also outlines the costing and pricing models for ESSO-NCMRWF and ESSO-INCOIS products and services.

Major assumptions and methodology outline

- This reports assumes the farming community as well as the fishing community as "reference groups", groups whose income gains would be considered at par with the accumulation of the uncommitted social income in the hands of the Government. The reasons for making these assumptions are spelt out in the report through an analysis of agricultural households (National Sample Survey Organisation-2014).

- The NSSO survey released in 2014 reveals that out of every 1,000 agricultural households, roughly 920 depend on crop production as the principal source of income. ESSO-NCMRWF-IMD's agro advisory group addresses the concern of this "reference group". In terms of social group stratification, roughly three-fourth of agricultural households belonged to Other Backward Class (OBC), Scheduled Caste (SC) and Scheduled Tribe (ST). The bulk of 90.3 million agricultural households belong to special social groups (74%); half these agricultural households belong either to Below Poverty Line group households and/or Antyodaya group (extremely poor) agricultural households. In view of these facts, income accruing to farmers has been considered in the study as equivalent to uncommitted social income in the hands of the government or farming community has been considered as a reference category for the study.

- As for the marine fishing communities, 'Below Poverty Level' fishermen form roughly two-third of traditional fishing families in the coastal states of West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra and Gujarat as well as in the Union Territories of Puducherry and Daman & Diu. Roughly one million people are active fishers, accounting for around 60 per cent of the occupational profile of fisher folk. Approximately 0.66 million people are involved in allied fishing activities such as marketing fish, making and repairing nets, curing and processing fish, peeling, labourer and others. 44 per cent of fisher folk are 'unschooled' (illiterate), while around 70 per cent have either only primary school education or are 'unschooled'. While marine fisheries accounts only for 0.33 per cent of total GDP, the foreign exchange earnings from exports of fisheries products is a significant 3 per cent of overall exports. This is one of the main reasons why the development of 3,218 villages located along the coast of 6,068 kilometres in the coastal states and Union Territories is a major agenda of the Government of India. In view of these facts, income accruing to fishers has been considered equivalent to uncommitted income in the hands of government for this study.

- The other key users like Indian Navy, the Indian Coast Guard, Indian Air Force, Indian Army, Ports, Maritime Boards, offshore oil and gas exploration industries and merchant shipping industries are important for economic development as well as strategic considerations.

- This report elicits perceptions of all the aforementioned stakeholders through meetings and group discussions. For farming community the latest NSSO survey of agricultural households covering around 90 million households was used. While, for the fishing community the Marine Fisheries Census 2010 from Central Marine Fisheries Research Institute (CMFRI) was referred.

Economic benefits of ESSO-NCMRWF-IMD weather predictions to the farming community-NSSO Survey

- In order to obtain the utility of weather predictions for the farmer, a limited survey of farmers was carried out by Reliance Foundation in partnership with NCAER team (herein after referred to as NCAER survey) covering 918 agricultural households across seven states in 35 districts. The objective of the survey was to elicit farmers' perception of the proportion of profit attributed to the use of weather prediction systems, crop-wise, during both the Kharif and Rabi seasons. This formed the sample basis to project net economic benefits, crop-wise, at the all-India level for the population of agricultural households estimated based on the unit level data of NSSO, which NCAER obtained for the exercise (herein after referred to as NSSO 2014 survey).

- The limited sample survey revealed that the weather predictions help farmers in two ways:
    - Control on farm expenses (seeds, fertilisers and plant protection chemicals application)
    - Increase in net farm income

  Thus, it was necessary not only to compute the overall net income from crop production, but also the expenditure incurred by farmers on farm inputs.

- Roughly Rs. one trillion is spent annually by farmers on farm inputs including irrigation. These expenses can be controlled if ESSO-NCMRWF-IMD numerical weather predictions are made available to all farmers in a timely manner. The total annual income from crop cultivation for 83 million agricultural households works out to Rs. 3.33 lakh crore (or Rs 3.3 trillion) at 2012-13 prices. The NSSO survey indicates that developing next-generation numerical weather forecast systems with high reliability for farmers in India has immense potential to benefit the reference group.

NCAER survey results on perceptions of Indian farmers on reliability & accuracy of ESSO-NCMRWF-IMD weather prediction systems: In order to verify whether ESSO-NCMRWF-IMD has been able to continuously improve its weather prediction systems, farmers were asked by RFIS-NCAER about reliability and accuracy of the information obtained:

- **ESSO-NCMRWF-IMD weather forecasts reliability:** More than two-third of the farmers confirmed that the ESSO-NCMRWF-IMD numerical weather predictions are extremely or very reliable. In total 93 per cent of farmers across states and districts said that such forecasts are quite reliable; only 3 per cent, mainly from Maharashtra, felt that the predictions are not reliable.
- **Improvement in reliability of weather forecasts over the past four years:** Farmers were asked whether they felt that the reliability of numerical weather predictions had improved in the past two to four years. The response across states and at the national level was an overwhelming 'Yes'. In fact, barring a few farmers in Madhya Pradesh and Gujarat, all the farmers agreed that the numerical weather predictions reliability had improved during the past two to four years.
- **Quantum of improvement:** Farmers' perceptions on the quantum of improvement in reliability were that there has been significant improvement; more than 95 per cent felt that the quantum of improvement was more than average.
- **Improvements in different parameters of weather prediction:** Farmers were asked to list the improvements on different parameters of numerical weather predictions. More than two-third of farmers felt that improvements had been in the:
    - accuracy of the forecasts
    - increased frequency of the forecasts
    - increased utility of the forecasts

  Roughly 57 per cent of farmers felt that there had been an improvement in the timeliness of the weather forecasts; however, a significant segment of farmers in Madhya Pradesh and Gujarat were not satisfied with the timeliness of weather forecasts.
- **Prioritising various components of weather predictions:** Farmers were asked to prioritise various components of weather predictions such as: rainfall, temperature, cyclone warning, and humidity. It was observed that the rainfall component has the highest priority in weather prediction across all states barring Odisha, which accords highest priority to cyclone warning.

- **Stages of cultivation where ESSO-NCMRWF-IMD weather forecasts are used:** Farmers were asked how they use the weather information in making decisions during farming stages such as:
    - Postponement of sowing time or sticking to the original schedule
    - Changing crop variety
    - Spraying pesticides for pest and disease control
    - Managing irrigation
    - Harvesting and post-harvesting operations

  Farmers responded that they used weather information to decide on postponement of sowing time, changing crop variety, managing irrigation and spraying pesticides and insecticides. They reported that they give equal importance to the use of weather information in each of these areas of operation. Harvesting and post-harvesting operations did not warrant the use of weather information except in the case of farmers from Tamil Nadu.

  Potential economic benefits of ESSO-NCMRWF-IMD weather prediction systems: Two approaches were used to assess the potential economic benefits:

- **Macro Approach:** Indian agriculture improved performance since 2004–05 is often attributed to policy initiatives undertaken since 2004–05. However an in-depth analysis reported in the Economic Section of the Twelfth Five-Year Plan, 2013 by the NITI Aayog(erstwhile Planning Commission) reveal that the agricultural growth of rain-fed areas has contributed to the renewed dynamism. To quote the Planning Commission (2013), "The growth acceleration since 2005 has therefore been much stronger in states with lower productivity and less irrigation. This suggests that the strategy may be correcting the past relative neglect which caused rainfed farming covering about 60% of arable land to perform well below potential." Thus, this acceleration can be attributed to the increased reliability and accuracy of the numerical weather prediction systems of the ESSO-NCMRWF that are disseminated roughly three to ten days in advance through the IMD to the farming community, which go a long way towards mitigating the risks associated with rain-fed farming. Of course, policy initiatives play a catalytic role. However, if the growth dynamism can be attributed to growth in rain-fed areas, then we can associate this phenomenon with the increased reliability, accuracy and awareness of weather prediction systems by the farming community.

- **Micro- approach:** To carry out an analysis using the micro-approach, we obtained unit-level agricultural household survey data (agricultural year July 2012–June 2013) from the NSSO in order to map production, area and net revenue from cultivation for around 150 crops at the state level as well as at the all-India level.
    - On this detailed data, we superimposed the perceptions of farmers on the net profit from cultivation, crop-wise, that can be attributed to ESSO-NCMRWF- IMD weather prediction systems both in kharif and rabi seasons, separately. This provided nation-wide potential economic benefits that can be attributed to increased reliability and accuracy of the ESSO-NCMRWF-IMD weather prediction systems. The potential economic benefits can be attributed to the increased robustness of numerical weather prediction systems developed by ESSO-NCMRWF, while the actual economic benefits realised would depend on the IMD's effectiveness in raising the awareness of the farming community and disseminating weather forecasts in a timely manner by partnering with NGOs and corporates.
    - Wheat, paddy, sugarcane and cotton are four principal crops that have the potential to use the weather prediction information of the ESSO-NCMRWF-IMD to generate an annual economic profit of Rs 42,000 crore. This would imply a gross economic benefit due to use of ESSO-NCMRWF-IMD weather prediction systems at Rs 3.3 trillion (Rs 330,000 crore) over the useful life at the social discount rate. Gross benefits need to be compared against investments made in the ESSO-NCMRWF-IMD to obtain net economic benefits.
    - The future value of past investments in ESSO-NCMRWF, including the investments in knowledge networks, totals Rs 485 crore. This is quite insignificant since the order of economic benefits is in trillions; any investments made to increase accuracy or obtain a finer resolution need to be welcomed.
    - The top 14 principal crops (from the top 10 per cent of crops surveyed) can use weather information and realise around Rs 60,000 crore economic profits annually. The top 28 principal crops (from the top 20 per cent of crops surveyed) have the potential to realise an annual economic benefit of Rs 67000 crore. The present value of economic benefits in the former case works out to Rs 4.7 trillion, while in the latter case it works out to Rs 5.2 trillion. The economic benefits to be realised are enormous; in comparison to the investments needed to obtain finer resolutions and improve accuracy.

Future direction for ESSO-NCMRWF: Location-based forecasts for power utilities generating renewable energy: The total installed generation capacity as on date is 245,000 MW of which 10 per cent is renewable. Renewable energy is completely weather dependent.

The ESSO-NCMRWF provides coordinate-wise forecasts for wind speed, wind direction, temperature, humidity and pressure. Efforts are on to provide forecasts of cloud cover to enable forecasts of power generation from solar plants.

- Forecasts of wind power generation need to be provided at one-hour intervals to the central grid authority with an accuracy of +/– 30% to avoid penalties. For instance, Tamil Nadu has a generating capacity of 12,000 MW, of which the wind power component is 7,000 MW. The state grid is not able to absorb more than 3,500 MW of cheaper wind power due to uncertainties. States with excellent wind power potential are Tamil Nadu, Gujarat and Rajasthan. States with good wind power potential are Karnataka, Maharashtra and Madhya Pradesh. States with excellent solar power potential are Gujarat and Rajasthan.

- Solar capacity will be around 100,000 MW by 2022; the cost of wind power is the lowest to date and wind turbines with 2.1 to 2.3 MW capacities are being added in place of 350 KW wind turbines. Solar power generation, currently in the range of Rs 6 to 8 per KWH, is likely to almost match thermal generation costs soon.

- India consumed 1.12 billion MWH during 2012 (source MOSPI); assuming the renewable energy consumption at 5 per cent of total electricity energy consumption, the carbon footprint saved would be around 0.0056 billion MWH. Since 1 MGH replacement by renewable energy can be equated to a saving of 1 ton of carbon-dioxide or 1 Certified Emission Reduction, it can be valued at around €6 or at Rs 400 (exchange rate 1 Euro = Rs 66.52 as on 12th March 2015). The savings would thus amount to Rs 22 billion or Rs 2,200 crore per year. If the renewable energy replacement to the extent of 10 per cent were achieved, the savings would be Rs 4,400 crore per year. Savings over the useful life would work out to Rs 17,600 crore in the former case and Rs 34, 500 crore in the latter case at 12 per cent social discount rate.

Potential economic benefits of providing Potential Fishing Zones (PFZ) along with Ocean State Forecasts (OSF) advisories to marine fisheries: We estimate total net economic benefits including environmental and ecological arising out of a limited survey of RFIS-ESSO-INCOIS interventions in the form of PFZ and OSF to fishers/boatmen. Environmental benefits are outlined as the benefit due to a reduction in overall energy consumption due to lower specific energy consumption per unit catch. Ecological benefits are outlined as the net gain in the new eco-system that arise out of the provision of PFZ advisories. The overall gain is estimated as the cumulative of economic, environmental and ecological benefits.

- NCAER-RFIS conducted an exclusive survey of the fishing community to assess the economic benefits. The survey covered boatmen (owners) as well as unskilled labour in these coastal villages in seven states in the year 2014. Net economic benefits of RFIS–ESSO-INCOIS interventions have been assessed as the additional economic benefits in the hands of boat owners, labourers and drivers during the post ESSO-INCOIS intervention period over the earlier fishing practice methods period prior to PFZ interventions.
    - For the same capacity, for fishing craft acquired during different periods the cost escalation factors were assessed using semi-log regression. The average cost escalation figure for motorised craft works out to 14.3%, while for mechanised craft it is 5.1%.
    - The economy of scale factor was assessed at 0.85 from the data collected from the RFIS-NCAER survey of 2014. Basic data on 21 craft during the field survey were used to compute gross economic benefits as well as benefits in mitigation of climate change environmental effects.

- **Economic benefits**
    - The economic analysis indicates that the real growth rate of gross value added in marine fisheries GDP can go up to 7.8 % per annum from the current level of 3.9% once the PFZ-OSF is operationalised uniformly across the country in all coastal areas.
    - It also indicates that the additional profit in the hands of fishers due to PFZ-OSF operations would be around Rs 3,000 crore, annuity. This annuity would amount to a present value of Rs 23,800 crore over a 25-year useful life. Since this is the reference income level, the economic benefit can be assumed to be Rs 23,800 crore as a result of the operationalisation of coupled atmospheric and ocean state forecasts. The gross investments in the PFZ and OSF departments of ESSO-INCOIS were a mere Rs 32 crore, arrived at as the future value of past investments at 12 per cent social discount rate.

- **Environmental benefits:**
    - Identification of PFZ results in saving diesel consumption since fishers now zero in on a particular area. The savings in diesel consumption result in a reduction in carbon dioxide emissions. A one litre saving in diesel consumption can reduce 2.63 kilograms of carbon dioxide emission. Since a reduction of 1 tonne of carbon dioxide mission is equivalent to 1 Certified Emission Reduction (CER), this can be valued in economic terms because such reductions are internationally traded. The environmental effect of savings in diesel consumption computed as carbon credit would work out to an annuity of Rs 36,200 crore or a present value of around Rs 2.84 trillion over the 25-year useful life, which is quite significant.

- **Ecological benefits:**
    - The labourers and drivers acknowledged the beneficial effects of the PFZ and OSF advisors. According to them, PFZ advisories are quite accurate; it has become less complicated to reach locations with fish shoals and their family members are assured of additional consumption benefits. The provision of PFZ and OSF information makes the crew and their family feel secure. Besides, the labourers' manual work has come down drastically, resulting in improved health and in an ability to spend more quality time with family members.

Economic benefits from the Ocean State Forecast to different users: The estimate of economic benefits of the Ocean State Forecast information for different user communities such as shipping community, maritime board, ports and harbours are based on interviews with the agencies and industry experts and varied data collated from these users. The methodology for estimation varies for each user based on the information provided due to involvement of sensitive users like the Indian Navy and Indian Coast Guard.

- The Indian Navy has been using OSF and Tsunami alert systems for providing oceanographic forecast to various agencies including Defence Research and Development Organization (DRDO) during its missiles launching programmes, Strategic Force Command along with identifying safe and strategic positioning of naval ships and submarines. The economic benefits were calculated using number of 'no mission go ahead' that were issued multiplied by the typical average of infructuous cost avoided in operations of mission. Since five 'no go ahead mission' advisories were provided since 2013 till date the net benefits during 2013-2015 works out to be Rs. 4,161.9 crore. The annuity of avoided expenditure will be Rs. 2,080 crore. The present value of annuity for 25 years at 12 per cent discount rate will be approximately Rs. 16,000 crore.
- The Indian Coast Guard uses the ESSO-INCOIS forecast to plan their operational activities and manage oil spill contingencies. Around 90 minor and major oil spills have occurred in the Indian water since 1982 and amount received from the polluters for about 17 such incidences was obtained. The total cost paid by polluters in 2015 prices for 15,211 tonne has been computed as Rs. 89.43 crore. The social discount rate of 12% has been used to compound the past prices in terms of 2015 prices. The per tonne cost paid by the polluter works out to Rs. 58,796 or USD 947. The PV of annuity of what polluter pays for an average annual oil spill of 4,000 tonnes, based on average oil spills incidents during the period 1988-2015, and would be Rs. 185 crore only.

- The economic benefits to the offshore industries were estimated based on Oil and Natural Gas Corporation (ONGC) new crude oil and gas production project. This project entails an investment of Rs 53,058 crore for drilling 45 wells in the east coast at 25 kilometres from the sea coast. The total PV of annuity of crude oil and gas from the project is estimated at Rs 3.68 trillion. If OSF has a catalytic effect on the smooth expansion of offshore oil and gas exploration activities, its net economic benefits can be equated to the present value of value additions in crude oil and gas production. The value addition is Rs. 3.74 trillion and benefit to cost ratio at 12% social discount rate is nearly 7.1.

- ESSO-INCOIS predicts the intensity of the storms and regions affected very accurately, the port authorities are able to adopt measures for just in time evacuation resulting in atleast 3 days of productivity per year for the major ports in Eastern Coast and 1.5 days in the Western Coast. Since, the revenue realization per tonne of the cargo handle was Rs. 250 per tonne, the economic value of the increased productivity works out to be Rs. 669 crore over the useful life at 12% social discount rate.

- The overall economic benefits due to OSF service would be the cumulative benefits realised by Indian Navy, India coast guard, value addition of oil and gas exploration etc. per our computations exceed Rs 3.7 trillion. The gross investments made by ESSO-INCOIS to provide OSF in 2015 prices is Rs 6.47crore (including recurring capital of Rs 2.41 crore).

Economic benefits from the Indian Tsunami Early Warning Centre ESSO-INCOIS: Official sources attached to the Odisha government sought Rs 1,900 crore as a contingency fund for Phailin work related to relief and restoration. The state government also estimated that Rs 5,832 crore from the National Disaster Resource Fund (NDRF) would be required to meet the total expenses. Thus, a contingency plan as well as actual expenditure for relocation and rehabilitation can be a significant expenditure running to a few thousand crore. Although, this is related to cyclones and not Tsunami, it can be used to comprehend the magnitude of expenditure involved in relocation and rehabilitation of affected population. The economic benefits of the Tsunami Early Warning Centre can be simply accessed by the list of under-sea earthquakes in the Indian Ocean Region for which a 'No Tsunami Threat' advisory issued by ITEWC, ESSO-INCOIS avoids relocation and rehabilitation expenditures of human settlement in the affected regions. In this section we list the 23 cases from 2007 where 'No Tsunami Threat' was issued. Even if we assume an expenditure of around Rs 3,500 crore for one relocation and rehabilitation (based on the Phailin case study), the cumulative savings would amount to Rs 80,500 crore for period of 7 years (2007 through 2014). This would translate into an annuity (savings due to "No Tsunami Threat") of Rs 11,500 crore or Rs 90,000 crore over the entire useful life.

- The compounded investment in the Tsunami Early Warning Centre since its inception was a mere Rs 133 crore in 2014 prices at the social discount rate of 12 per cent. Obviously, the gross economic benefit far exceeds such gross investments.

- In view of significant economic benefits emanating from ESSO-NCMRWF and ESSO-INCOIS services, costing based on average cost for new services are envisaged; estimate for such standard cost are provided in this study. The stress on average costs basis pricing is to encourage a wider application of services rather than the revenue maximisation from the potential users. In this study, the unit of measurement of cost of services is 'Rupees per hour' for all the services provided by ESSO-NCMRWF and ESSO-INCOIS. The cost refers to the average of all the costs incurred by the agency for providing varied services to different end-users. The stress on average costs basis pricing is to encourage a wider application of services rather than the revenue maximisation from the potential users.

Costing of services of The ESSO-NCMRWF and ESSO-INCOIS: This study measures the cost of providing weather- and ocean-related information services by two government agencies—ESSO-INCOIS and ESSO-NCMRWF.

- The cost refers to the average of all the costs incurred by the Agency for providing varied services to different end-users and the unit of measurement of cost of services is 'Rupees per hour' for all the services provided by ESSO-NCMRWF/ESSO-INCOIS. The costs data are as given by the respective agencies for this study.

- ESSO-NCMRWF activities can be categorised intodata assimilation, modelling, and testing & dissemination of products. Various elements of cost relating to Data Assimilation were added to arrive at the assimilation activities, and similarly for other two activities already mentioned. Since the final output to outside users were by the 'Testing and Dissemination of products group' the costs of other two groups were incorporated into the costs of this group to arrive at the total cost of the two category services provided by the agency.

- In ESSO-INCOIS, there are six functional groups with two of them performing supporting activities, one of them engaged in observation and collection of data for the purpose of data management by another group. The out-put services are being provided from three functional groups – Information Services and Ocean Sciences Group (ISG), Advisory Services

and Satellite Oceanography Group (ASG) and Data Management Group (DMG). The costs for all the six groups were computed on an average basis, as the first initial step. Then the costs of supporting functional groups were distributed among other four groups on equal basis. After this, the costs of MOG (group engaged in observation and collection of data) were transferred to DMG for provision of services to users. The final cost structure showed the average total annual costs of three product-services provided by functional groups – ISG, ASG and DMG.

Guidelines for pricing product and services of ESSO-INCOIS and ESSO-NCMRWF: The decision to charge for product-services has become an integral feature of government agencies, though there are problem of consistency between the pricing policies adopted in different areas and the problem of executing the pricing decisions effectively. In the cases of ESSO-INCOIS and ESSO-NCMRWF also, the problems exist and an appropriate policy framework could only be evolved over the years. The guidelines set out herewith are aimed to recover full cost of the services, though in case of some end-users, who receive the product-services, the charges may not be levied or be less than cost-recovery due to specific reasons.

- The first principle is to levy a charge based on cost incurred for each service, in the same fashion across users unless users are categorised into reference groups/ governmental agencies that are exempted from any charge.
- Secondly, it is necessary to bear in mind that cost in collecting the tariff levied may overweigh the quantum of tariff itself.
- Thirdly, positive externalities of the products/services should be taken into consideration while deciding on service charges/prices.
- Lastly, pricing models may differ for customised forecasts.

- Based on these guidelines, we may charge only annual departmental overheads, if the demand is sensitive to prices. Services used by commercial entities may call for a levy of a cost plus pricing model. By factoring- in 'intellectual fees' in to the cost we can arrive at the price/charge, which is another important version of cost plus pricing model. Prices can be arrived differently across different input-equipment or different users or different location/time. Again, economic pricing model is one where price is equivalent to full cost, excluding transfer payments if any, including a margin for capital recovery.

- We have presented a few illustrative examples of arriving at the price of the services of ESSO-INCOIS as well as ESSO-NCMRWF, under the cost-plus pricing model. It contains two

alternative prices – one by adding 12% to the cost as the margin and another by adding 40% for intellectual fees. Equipment as a source of differentiation-pricing model was derived for few DMG (Data Management Group) product-services, as another illustrative pricing model. In all the pricing models, per user/customer price for any service can be arrived by dividing the price, under the model, by the number of chargeable users for that service.

Chapter I: ESSO-NCMRWF and its Economic Benefits

Chapter I.1ESSO-NCMRWF: History, Mission & Objectives

History

The National Centre for Medium Range Weather Forecasting (ESSO-NCMRWF) was created in the aftermath of the extreme climatic events in north-west India during the winter of 1983-84 when the Rabi crops were being harvested. A high-powered committee chaired by Professor Yashpal, who was the Chief consultant of the NITI Aayog (former Planning Commission) noted the success of the European Centre for Medium Range Weather Forecasts (ECMWF) in making dynamic weather forecasts three to ten days in advance. The committee desired that an Indian Centre be set up for Medium Range Weather Forecasts on the pattern of ECMWF.

The ECMWF was set up jointly by 14 countries in Europe during 1978-79 to make dynamic weather forecasts based on a global data assimilation and forecast system using an Atmospheric General Circulation Model (AGCM). The Yashpal Committee found their numerical weather prediction products for various applications were both relevant and useful. The desire to set up a similar institute to meet India's requirements for agricultural operations in each of the 127 agro-climatic zones resulted in the setting up of the ESSO-NCMRWF in India in 1988. The ESSO-NCMRWF was set up to develop an advanced system of numerical weather forecasts through in-house research and development for bringing out highly reliable weather forecasts.

Mission and Objectives

The mission of the organisation till date remains the same, viz., to develop an advanced system of numerical weather forecasts through in-house research and development for bringing out highly reliable weather forecasts, although the scope has been expanded to include forecasts not only for India but also for neighbouring countries.

The ESSO-NCMRWF set up during 1988 had four important objectives at that time:

1. To generate products for dynamic numerical weather prediction for various applications three to ten days in advance; the focus was to be the application of an Analysis- Forecast system with a suitable AGCM for generating dynamic weather forecasts.
2. To acquire and commission a supercomputer and supportive infrastructure for generating numerical weather forecasts.

3. To establish a network of 127 Agro-Meteorological Field Units (AMFUs) for rendering an appropriate Agricultural Advisory Service (AAS) to prepare and disseminate crop-specific advisories based on ESSO-NCMRWF's medium- range weather forecasts.

4. To develop Statistical Interpretation models based on the Perfect Prognostic Method (PPM) to generate location-specific forecasts.

After the AAS mechanism was stabilised, it was transferred to the IMD in 2008 to be merged with the IMD's agro-meteorological activities.

ESSO-NCMRWF is now mandated to continuously develop next generation numerical weather forecast systems, in terms of reliability and accuracy over India and neighbouring regions through research and development for subsequent operational use.

The ESSO-NCMRWF acquired a CRAYXMP-14 supercomputer for real-time assimilation of all available terrestrial ocean, satellite and aircraft observations in order to produce representative initial conditions for a global AGCM that could generate deterministic tropical weather prediction products. A High Performance Computing (HPC) facility was set up, which served as the only centre capable of generating dynamic numerical weather prediction models for more than a decade. In 1993, the AGCM started producing forecasts three days in advance for the India Meteorological Department (IMD), which disseminated it further down the chain. The model was rather coarse at that time with a horizontal resolution of 150 km and 18 levels in the vertical. The AGCM was upgraded to the T254L64 (horizontal resolution of about 50 km and 64 levels in the vertical) in 2007.

The AGCM was gradually upgraded—to T382L64 (horizontal resolution of about 35 km and 64 levels in the vertical) in the year 2010 and then to T574L64 (horizontal resolution of about 22 km and 64 levels in the vertical) in the year 2011. In November 2011, the ESSO-NCMRWF handed over the T574L64 model to IMD for their operational use. Currently, the ESSO-NCMRWF is upgrading the AGCMto N768L70(horizontal resolution of about 17 km and 70 levels in the vertical). The Indian monsoon is a fully coupled system, where ocean, atmosphere and land-surface interact and play dominant roles simultaneously. ESSO-NCMRWF is now developing a coupled ocean-atmosphere modelling system for extending the temporal range of forecasts.

Table I.1.1 ESSO-NCMRWF: Installation of HPC resources

Year	2002	2006	2010	2012	2014
Details	CRAY-SVI	CRAY-XIE	IBM-P6 24 Flops	IBM-P6 24 Flops	IBM iDataPlex (350 T flops) Installation in progress
National Knowledge Network				Part of National Knowledge Network	
Resolution of the AGCM	T80L180 50 km horizontal 18 levels vertical	T254L64 50 km horizontal 64 levels vertical	T382L64 35 km horizontal 64 levels vertical	T574L64 22 km horizontal, 64 levels vertical	N768L70 17 km horizontal 70 levels vertical

Source: ESSO-NCMRWF

Apart from agricultural stakeholders, the fishing community is the other primary stakeholder being served by the ESSO-NCMRWF through ESSO-INCOIS. The ESSO-NCMRWF' sends its operational products on surface winds and fluxes over the ocean surface to ESSO-INCOIS Hyderabad, which in turn uses it to drive their ocean and wave models and the final products are served to the fishing community through NGOs.

Customised forecasts

The ESSO-NCMRWF works closely for wider adoption of customised products with organisations in defence and disaster management, and with ISRO for satellite launches, BARC and DAE for offsite nuclear emergencies. It provides operationalproducts on surface winds and fluxes over the ocean surface to the Indian Navy.

ESSO-NCMRWF's capability and scientific knowledge base are being leveraged not only for India but also for neighbouring countries in Southeast Asia and in Africa. The Regional Integrated Multi-Hazard Early Warning System for Africa and Asia (RIMES) is an international and intergovernmental institution, owned and managed by its Member States, for the generation and application of early warning information. The RIMES has 12 member countries: Bangladesh, Cambodia, Comoros, India, Lao PDR, Maldives, Mozambique, Papua New Guinea, Philippines, Seychelles, Sri Lanka and Timor-Leste and 19 other collaborating countries. ESSO-NCMRWF has started providing products to all the member and collaborating countries of RIMES.The ESSO-NCMRWF's achievements over the 26 years of its existence shows that it has been serving the mission of generating numerical weather prediction system in an exemplary manner,through the

comprehensive development of numerical weather prediction systems by in-house R&D. However, an empirical examination of the following is needed:

1. Whether ESSO-NCMRWF has been continuously able to improve its weather prediction system with high reliability, from the perceptions of main stakeholders—farmers— that the ESSO-NCMRWF is serving in association with IMD.

2. Whether the support given by ESSO-NCMRWF to ESSO-INCOIS for OSF is successful from the perspective of the main stakeholder—the fishing community

This report is to fulfil this void. Through a field survey of farmers across seven states in 35 districts, it examines whether there has been continuous improvement in weather prediction systems with high reliability. It also examines empirically whether the Ocean State Forecasting is sufficiently reliable enough through a survey of fishers in coastal villages.

Chapter I.2 Key Indicators of the Situation of Indian Agricultural Households Engaged in Crop Production

Agricultural households are surveyed once in 10 years, and the latest survey was conducted during the agricultural year July 2012 through June 2013. The National Sample Survey Organisation (NSSO) of the Ministry of Statistics and Programme Implementation (MOSPI) surveyed around 70,000 agricultural households spread across 29 states and 7 Union Territories to arrive at key indicators in December 2014. We were able to draw out the status of farmers from this NSSO dataset. The key results from the survey about the situation of Indian agricultural households are discussed in this chapter.

1. **Number of agricultural households by State:** During the agricultural year July 2012 through June 2013, India had around 90.3 million agricultural households that represented 58 per cent of estimated rural households in India. This was found in an all-India survey spread across states and UTs; of the major states, Uttar Pradesh alone accounted for more than 20 per cent of India's agricultural households; the other states that accounted for more than 7 per cent share of all-India agricultural households were Maharashtra, Rajasthan, Bihar and West Bengal as shown in Table I.2.1. In other words, five main states, viz., Uttar Pradesh, Rajasthan, Maharashtra, Bihar and West Bengal account for around 50 per cent of the 90.3 million agricultural households.

2. **Principal source of income of agricultural households:** Of the 90 million agricultural households, roughly 83 million households (92%) were engaged in crop production as their primary occupation and source of livelihood. This means that for 1,000 agricultural households, roughly 920 were engaged in crop production. Since the main focus of the ESSO-NCMRWF-IMD weather advisories is to serve agricultural households that are engaged in crop production, we have shown the distribution by state & UT of agricultural households principally engaged in crop production in Table I.2.1. (Indicated as no. of households per 1,000 agricultural households primarily engaged in crop production).

Table I.2.1: Estimated number of agricultural households, percentage share in rural households in the major states during the agricultural year July 2012 – June 2013

State	Estimated no. of agricultural households (00)	Estimated no. of rural house-holds (00)**	Agricultural households as percentage of rural house-holds (%)	Estimated no. of agricultural households per cent share of all-India	No. per 1000 agricultural households engaged in crop production
Andhra Pradesh	35,968	86,763	41.5	4.0%	883
Assam	34,230	52,494	65.2	3.8%	955
Bihar	70,943	140,611	50.5	7.9%	900
Chhattisgarh	25,608	37,472	68.3	2.8%	978
Gujarat	39,305	58,719	66.9	4.4%	832
Haryana	15,693	25,849	60.7	1.7%	721
Jharkhand	22,336	37,516	59.5	2.5%	982
Karnataka	42,421	77,430	54.8	4.7%	961
Kerala	14,043	51,377	27.3	1.6%	980
Madhya Pradesh	59,950	84,666	70.8	6.6%	944
Maharashtra	70,970	125,182	56.7	7.9%	959
Odisha	44,935	78,120	57.5	5.0%	979
Punjab	14,083	27,552	51.1	1.6%	664
Rajasthan	64,835	82,722	78.4	7.2%	906
Tamil Nadu	32,443	93,607	34.7	3.6%	775
Telangana	25,389	49,309	51.5	2.8%	961
Uttar Pradesh	180,486	241,328	74.8	20.0%	914
West Bengal	63,624	141,359	45	7.1%	962
All India*	**902,011**	**1,561,442**	**57.8**	**100.0%**	**920**

Source: NSS KI (70/33): Key Indicators of Situation of Agricultural Households in India.

** All-India figures include all States and UTs, which is not shown in the Statement*

*** The estimate of rural households as per the results of the Land and Livestock Holding Survey of NSSO 70th round*

3. Agricultural households below poverty level (BPL) and Antyodaya (extremely poor) ration cards: At the all-India level, around 36 per cent of agricultural households hold Below Poverty Level (BPL) ration cards, and 5 per cent hold Antyodaya (extremely poor) ration cards. In total, around 41 per cent of agricultural households belong to either the BPL level or below. Considering that around 12 per cent do not have any ration card, the proportion of agricultural households that are either at BPL or below can be expected to lie in the range of 41% (minimum) to 53% (maximum). Thus, the ESSO-NCMRWF-IMD advisory services to farmers can be considered very relevant to BPL or below-BPL households. The service is of great national significance, as income accruing to BPL families is considered as valuable as the uncommitted social income accruing in the hands of the government. Besides, this scenario does not vary significantly across States/UTs in Table I.2.2.

Table I.2.2: Per 1000 distribution of agricultural households by type of ration card for majorstates

State	Antyodaya	BPL	Other	No	All	Estd. no. of agricultural households (00)
Andhra Pradesh	37	918	22	23	1,000	35,968
Assam	40	369	403	188	1,000	34,230
Bihar	42	450	369	139	1,000	70,943
Chhattisgarh	41	570	299	90	1,000	25,608
Gujarat	26	340	616	18	1,000	39,305
Haryana	26	87	862	24	1,000	15,693
Jharkhand	58	350	224	369	1,000	22,336
Karnataka	58	651	196	95	1,000	42,421
Kerala	12	229	743	15	1,000	14,043
Madhya Pradesh	53	365	406	176	1,000	59,950
Maharashtra	57	303	538	101	1,000	70,970
Odisha	36	488	238	238	1,000	44,935
Punjab	38	175	739	49	1,000	14,083
Rajasthan	37	243	659	60	1,000	64,835
Tamil Nadu	41	321	630	8	1,000	32,443
Telangana	15	927	28	30	1,000	25,389
Uttar Pradesh	81	178	527	215	1,000	180,486
West Bengal	31	317	633	19	1,000	63,624
All-India*	**49**	**364**	**464**	**123**	**1,000**	**902,011**

Source: NSS KI (70/33): Key Indicators of Situation of Agricultural Households in India

*Note: * based on all States and UTs, including States and UTs not shown in this Statement*

4. Analysis of sources of income of agricultural households by deciles grouping of consumption expenditure: The above observations at the all-India level can be verified through an analysis of income of agricultural households classified by decile class of Monthly Per Capita Expenditure (MPCE). The average monthly income from different sources such as cultivation, farming of animals for each decile class of MPCE is **given in the Table I.2.3.The analysis reveals that only the last two decile groups are able to save out of the family's income (around 23 million out of 90.2 million agricultural households are able to save); the remaining 67 million would only be able to increase their level of consumption expenditure. The analysis reveals the vulnerable nature of our agricultural households and the findings reinforce our earlier observations that a significant proportion of agricultural households belong to below BPL category.

5. Analysis of agricultural households by social groups: In terms of social group, roughly three-fourth of agricultural households belonged to Other Backward Class (OBC), Scheduled Caste (SC) and Scheduled Tribe (ST). The bulk of 90 million agricultural households belong to special social groups (74%); half these agricultural households belong either to Below Poverty Line group households and/or Antyodaya group (extremely poor) agricultural households.

Table I.2.3: Average monthly income from different sources, consumption expenditure and net investment in productive assets (Rs.) per agricultural household for each decile class of MPCE (July 2012- June 2013)

Decile class of MPCE	Income from wages	Net receipt from cultivation	Net receipt from farming animals	Net receipt from non-farm business	Total income	Total consumption expenditure	Net investment in productive assets (Rs)	Estd. no. of agricultural households* (00)
1	1,729	1,533	478	130	3,870	3,537	243	65,652
2	1,624	1,858	642	139	4,263	4,337	131	71,640
3	1,716	2,046	578	357	4,697	4,708	306	77,307
4	1,685	2,059	732	263	4,739	4,933	420	82,771
5	2,036	2,445	651	339	5,471	5,358	242	85,534
6	2,049	2,653	821	308	5,830	5,515	390	92,140
7	1,679	2,944	596	484	5,703	5,896	699	96,285
8	1,822	3,106	671	524	6,122	6,385	253	101,973
9	2,424	3,737	723	546	7,430	7,169	627	108,704
10	3,265	6,306	1,414	1,473	12,458	11,107	1,339	120,033
All classes	**2,071**	**3,081**	**763**	**512**	**6,426**	**6,223**	**513**	**902,039**

Source: NSS KI (70/33): Key Indicators of Situation of Agricultural Households in India

*Note: *Estimated number of households based on the common households of Visit 1 and Visit 2 differs from the estimate based only on Visit 1 households due to the multiplier effect.*

In view of these facts, income accruing to farmers has been considered in the study as equivalent to uncommitted social income in the hands of the government or farming community has been considered as a reference category for the study.

6. Agricultural households expenditure on farm inputs: The sample survey of farmers carried out by the Reliance Foundation–NCAER indicates that the weather predictions help in two ways:

   - Control on farm expenses (seeds, fertilisers and plant protection chemicals application)
   - Increase in net farm income

Thus, it was necessary not only to compute the overall net income from crop production, but also the expenditures incurred by farmers on farm inputs.Roughly Rs. one trillion is spent (Table I.2.4), annually, on farm inputs including irrigation. These expenses can be controlled if ESSO-NCMRWF-IMD numerical weather predictions are made available to all farmers in a timely manner.

Table I.2.4 Agricultural household expenditure on all farm inputs including irrigation

Farm input item	**Expenses per household involved in crop production**	**Total expenses in the agriculture year July 2012-June 2013**
	Per month	*Rs crore*
Seeds	250	24,880
Fertilisers & Manure	526	52,350
Plant protection chemicals	165	16,420
Irrigation	70	6,970
All farm inputs including irrigation	1,011	100,620

Source: NSS KI (70/33): Key Indicators of Situation of Agricultural Households in India

7. **Agricultural households' value of output in crop production:** The value of output of agricultural households engaged in crop production is traced below in Table I.2.5.

Table I.2.5: Value of output per household as well as for all agricultural households (8.294 crore) engaged in crop production

Item	**Revenue per month per household involved in crop production (Rs.)**	**Total revenue (Rs crore) From crop production July 2012-June 2013**
Crop products	5,200	517,610
By-products	329	32,750
Pre-harvest sale	13	1,290
Total Revenue	5,542	551,650

Source: NSS KI (70/33): Key Indicators of Situation of Agricultural Households in India

8. **Agricultural households' net revenue from crop production:** The net value of crop production is arrived at as the difference between total revenue and total expenses in TableI.2.6. The total annual income from crop cultivation for 83 million agricultural households works out to Rs 3.33 lakh crore at 2012-13 prices, or Rs 3.3 trillion.

Table I.2.6: Net revenue from crop production per agricultural household

Item	Total per month per household in crop production	Total for 8.295 crore households (Rs crore) in 2012-13
Total Revenue	5,542	551,650
All farm inputs including irrigation	1,011	100,620
All other inputs including labour, repair and maintenance etc.	1,181	117,560
Net Revenue from crop production	3,350	333,500

Source: NSS KI (70/33): Key Indicators of Situation of Agricultural Households in India.

Chapter I.3 Perceptions of Indian Farmers on Reliability & Accuracy of ESSO-NCMRWF-IMD Weather Prediction Systems

A survey of farmers across seven states was carried out by Reliance Foundation in partnership with an NCAER team. The objective of this survey was to assess farmers' association of profit potential to weather forecast, which was not covered under the NSSO. The sample was limited to districts where the Reliance Foundation had major networks in surveying agricultural households. Also, the limited sample survey was used to extrapolate the results at the NSSO sample level crop wise. The survey covered 918 agricultural households in 35 districts. The profile of the surveyed households are given in Table I.3.1.

Table I.3.1: Sample survey of agricultural households by district

District	Sample size	Per cent share
East Godavari	42	4.6
Krishna	34	3.7
Nellore	41	4.5
Srikakulum	10	1.1
Visakhapatnam	10	1.1
West Godavari	39	4.2
Total (Andhra Pradesh)	**176**	**19.2**
Bharuch	14	1.5
Junagadh	11	1.2
Surendranagar	9	1
Total (Gujarat)	**34**	**3.7**
Akola	58	6.3
Amravati	61	6.6
Buldhana	29	3.2
Hingoli	50	5.4
Nanded	29	3.2
Parbhani	28	3
Wardha	36	3.9
Washim	33	3.6
Yavatmal	41	4.5
Total (Maharashtra)	**365**	**39.7**
Balasore	10	1.1
Bhadrak	10	1.1
Ganjam	20	2.2
Jagatsinghpur	20	2.2
Total (Odisha)	**60**	**6.5**
Nettapakkam commune	1	0.1

Table I.3.1: Sample survey of agricultural households by district

District	Sample size	Per cent share
Puducherry	33	3.6
Villianur	8	0.9
Total (Puducherry)	**42**	**4.6**
Ariyalur	13	1.4
Cuddalore	33	3.6
Dindigul	23	2.5
Nagapattinam	32	3.5
Pudukkottai	50	5.4
Ramanathapuram	28	3
Thanjavur	28	3
Theni	29	3.2
Total (Tamil Nadu)	**236**	**25.7**
Dindori	3	0.3
Jabalpur	2	0.2
Total (Madhya Pradesh)	**5**	**0.5**

Source: Reliance Foundation – NCAER Survey 2014.

The survey covered agricultural households holding 16,800 hectares of irrigated land and 9.500 hectares of rain-fed land. The state-wise proportion of irrigated and rain-fed land holding is shown Table I.3.2.The proportion of irrigated land to rain-fed cultivated land was 2:1 in the survey.

Table I.3.2: Irrigated and rain-fed cultivated land by state

State	Total irrigated land (ha)	Total rain-fed land (ha)	Per cent irrigated land	Per cent rain-fed land
Andhra Pradesh	434.1	12.8	97	3
Gujarat	5.3	42.4	11	89
Madhya Pradesh	1	2.5	29	71
Maharashtra	607.4	764.5	44	56
Odisha	41.7	44	49	51
Puducherry	154.2	2	99	1
Tamil Nadu	435.6	88.2	83	17
All-India	**1,679.3**	**956.4**	**64**	**36**

Source: Reliance Foundation – NCAER Survey 2014.

Survey Results

I. **Farmers perception about profit attributed to weather prediction system:** Farmers were surveyed on their perceptions of profit attributable to the use of weather prediction systems during both the Kharif and Rabi seasons. Their perceptions collated crop-wise for both seasons are given in Tables I.3.3 and I.3.4.

Table I.3.3: Farmers' perceptions on profit attributable to the use of ESSO-NCMRWF-IMD weather prediction systems crop-wise during kharif season

Kharif					
Crop	**Total Cult Area (Acre)**	**Total Prod (Tonnes)**	**Harvest Value (Rs./tonne)**	**Profit (Rs./ tonne)**	**Profit due to ESSO-NCMR-WF-IMD (as per cent of net profit)**
Banana	49	190	40,473	21,682	25%
Black gram	179	35	43,142	30,148	25%
Chillies	4	4	50,000	37,500	25%
Cotton	1,017	630	34,722	24,015	25%
Ginger	4	2	50,000	43,750	25%
Green gram	53	20	11,052	10,650	25%
Groundnut	41	46	36,146	15,886	25%
Jowar	41	11	45,920	37,115	25%
Maize	29	40	8,944	6,322	25%
Okra	2	1	10,000	5,833	25%
Paddy	1,666	9,919	3,665	1,526	15%
Pulses	63	4	20,554	32,703	25%
Ragi	3	0	29,667	23,667	25%
Red gram	953	295	39,927	26,525	25%
Sesame	57	57	18,833	10,505	25%
Sugarcane	70	1,505	2,831	2,145	25%
Tapioca	1	9	4,300	2,078	25%
Tomato	7	11	1,818	11,364	25%
Vegetables	13	32	9,703	6,109	25%
Wheat	4	3	15,000	8,333	25%

Source: Reliance Foundation – NCAER Survey 2014.

Table I.3.4: Farmers' perceptions on profit attributable to the use of ESSO-NCMRWF-IMD weather prediction systems crop-wise during Rabi season

Crop	**Total Cult Area (Acre)**	**Total Prod (Tonnes)**	**Harvest Value (Rs./tonne)**	**Profit (Rs./ tonne)**	**Profit due to ESSO-NCMR-WF-IMD (as per cent of net profit)**
Banana	42	666	8,166	5,715	25%
Bengal gram	662	384	22,404	14,766	25%
Bitter gourd	1	4	12,000	9,500	25%
Black gram	80	71	9,782	4,761	25%
Brinjal	4	13	18,077	4,615	25%
Cashew	1	0	200,000	200,000	15%
Chillies	49	45	34,349	24,592	25%

Cotton	64	41	16,390	10,854	25%
Ginger	3	1	50,667	39,000	25%
Green gram	134	36	33,079	20,789	25%
Groundnut	98	159	19,774	8,687	25%
Jowar	27	13	16,190	16,667	25%
Lemon (Lime)	2	10	20,000	15,000	25%
Lentil	2	0	22,500	14,000	25%
Maize	24	39	9,249	4,868	25%
Mango	17	7	61,538	38,462	25%
Marigold	1	3	25,000	10,000	25%
Mulberry	2	20	2,700	1,700	25%
Mustard	39	13	29,918	15,396	25%
Paddy	1,572	32,597	1,242	509	15%
Pointed gourd	1	2	30,000	22,500	25%
Potato	4	1	17,273	7,273	25%
Pulses	37	19	9,518	21,838	25%
Ragi	15	14	12,263	4,161	25%
Red gram	5	1	10,000	40,000	25%
Sesame	22	35	14,685	6,481	25%
Sugarcane	63	1,493	2,389	1,603	25%
Sunflower	27	11	36,667	19,630	25%
Sweet Corn	2	1	62,500	12,500	25%
Tapioca	21	212	5,792	3,014	25%
Tomato	9	105	0	2,743	25%
Vegetables	14	9	48,351	31,404	25%
Watermelon	4	45	6,444	3,444	25%
Wheat	267	202	18,398	11,067	25%

Source: Reliance Foundation – NCAER Survey 2014.

II. Farmers' perceptions of reliability, accuracy & timeliness of ESSO-NCMRWF-IMD Weather Prediction Systems

A. Reliability of ESSO-NCMRWF-IMD weather forecasts

In order to empirically verify whether ESSO-NCMRWF-IMD has been able to continuously improve its weather prediction systems, farmers were asked whether they found ESSO-NCMRWF-IMD information reliable.

- More than two-third of the farmers confirmed that the ESSO-NCMRWF-IMD numerical weather predictions are extremely reliable or very reliable. They were quite pleased to note the extreme reliability of ESSO-NCMRWF-IMD forecasts.

- More than 93 per cent of farmers across states and districts said that the ESSO-NCMRWF-IMD weather prediction forecasts are quite reliable; only 3 per cent, mainly from Maharashtra, felt that the predictions are not reliable. (Table I.3.5)

Table I.3.5: If you use IMD weather information, how reliable do you find the information provided by IMD? State-wise responses in per cent (%)

State	Extremely reliable	Very Reliable	Reliable	Moderately reliable	Not reliable	Total
Andhra Pradesh	48	45	7	0	0	100
Gujarat	0	3	91	6	0	100
Madhya Pradesh	20	0	80	0	0	100
Maharashtra	12	39	36	6	7	100
Odisha	60	37	3	0	0	100
Puducherry	45	52	2	0	0	100
Tamil Nadu	37	31	28	3	0	100
All India	**29**	**37**	**27**	**3**	**3**	**100**

Source: Reliance Foundation – NCAER Survey 2014.

B. Improvement in reliability of weather forecasts over the past four years

Farmers were asked whether they felt that the reliability of numerical weather predictions had improved in the past two to four years. The response across states and at the national level was an overwhelming 'Yes'. In fact, barring a few farmers in Madhya Pradesh and Gujarat, all the farmers agreed that the numerical weather predictions reliability had improved during the past two to four years (Table I.3.6).

Table I.3.6: If you use IMD weather information, has the reliability of the weather information improved in the past 2 to 4 years? In per cent (%)

State	Yes	No	Total
Andhra Pradesh	98	2	100
Gujarat	41	59	100
Madhya Pradesh	40	60	100
Maharashtra	87	13	100
Odisha	100	0	100
Puducherry	100	0	100
Tamil Nadu	94	6	100
All India	**90**	**10**	**100**

Source: Reliance Foundation – NCAER Survey 2014.

C. Farmers' perception on the quantum of improvement

Farmers' perception on the quantum of improvement in reliability was that there has been significant improvement; more than 95 per cent felt that the quantum of improvement was more than average (Table I.3.7).

Table I.3.7: If it has improved, how large is the quantum of improvement?

State	More than average	Average	Less than average	Total
Andhra Pradesh	75	24	1	100
Gujarat	32	65	3	100
Madhya Pradesh	40	60	0	100
Maharashtra	29	56	15	100
Odisha	100	0	0	100
Puducherry	100	0	0	100
Tamil Nadu	74	25	2	100
All India	57	36	7	100

Source: Reliance Foundation – NCAER Survey 2014.

D. Farmers' perception on improvements in different parameters of weather prediction

Farmers were asked to list the improvements on different parameters of numerical weather predictions. More than two-third of farmers felt that improvements had been in the:

- accuracy of the forecasts
- increased frequency of the forecasts
- increased utility of the forecasts

Roughly 57 per cent of farmers (Table I.3.8) felt that there had been an improvement in the timeliness of the weather forecasts; however, a significant segment of farmers in Madhya Pradesh ad Gujarat were not satisfied with the timeliness of weather forecasts.

Table I.3.8: If you use ESSO-NCMRWF-IMD weather information, what are the changes in the information you have been receiving for the past 4 years? (% of farmers reporting improvements on different parameters

State	Improvement in frequency of dissemination	Improvement in accuracy of the information	Improvement in timeliness of dissemination	Improvement in utility of information
Andhra Pradesh	73	71	34	74
Gujarat	44	9	9	12
Madhya Pradesh	60	100	0	60
Maharashtra	99	67	93	82
Odisha	60	47	53	52
Puducherry	88	68	46	90
Tamil Nadu	40	74	31	27
All India	**74**	**67**	**57**	**62**

Source: Reliance Foundation – NCAER Survey 2014.

E. Prioritising Various Components of Weather Predictions

Farmers were asked to prioritise various components of weather predictions such as:

- Rainfall
- Temperature
- Cyclone warning
- Humidity

Their prioritisation on components of weather predictions are given in Table I.3.9:

Table I.3.9: Prioritisation on components of weather prediction systems

State	**Score 3.0–4.0**	**Score 2.0–3.0**	**Score 1.0–2.0**	**Score 0.0–1.0**
	Rank 1	**Rank 2**	**Rank 3**	**Rank 4**
Andhra Pradesh	Rainfall	Cyclone warning	Temperature	Humidity
Gujarat	Rainfall	Cyclone warning	Temperature	Humidity
Madhya Pradesh	Rainfall	Temperature	Humidity	Cyclone warning
Maharashtra	Rainfall	Temperature	Cyclone warning	Humidity
Odisha	Cyclone warning	Rainfall	Temperature	Humidity
Puducherry	Rainfall	Cyclone warning	Temperature	Humidity
Tamil Nadu	Rainfall	Temperature	Cyclone warning	Humidity
All India	**Rainfall**	**Cyclone warning**	**Temperature**	**Humidity**

Source: Reliance Foundation – NCAER Survey 2014.

As can be observed, the rainfall component has the highest priority in weather prediction across all states barring Odisha, which accords the highest priority to cyclone warning.

F. Stages of cultivation where ESSO-NCMRWF-IMD Weather forecasts are used

Farmers were asked how they use the weather information in making decisions during farming stages such as:

- Postponement of sowing time or sticking to the original schedule
- Changing crop variety
- Spraying pesticides for pest and disease control
- Managing irrigation
- Harvesting and post-harvesting operations

Farmers responded that they used weather information to decide on postponement of sowing time, changing crop variety, managing irrigation and spraying pesticides and insecticides. They said that they give equal importance to the use of weather information in each of these areas of operation. Harvesting and post-harvesting operations did not warrant the use of weather information except in the case of farmers from Tamil Nadu as shown in Table I.3.10.

Table I.3.10: What are the areas where you use ESSO-NCMRWF-IMD weather information? Per cent

State	Postponement of sowing time	Change in crop/ variety	Pest & disease control	Irrigation management	Harvesting & post-harvesting	Total
Andhra Pradesh	22	38	20	21	0	100
Gujarat	24	32	22	22	0	100
Madhya Pradesh	33	0	33	33	0	100
Maharashtra	25	25	25	25	0	100
Odisha	29	21	26	25	0	100
Puducherry	25	31	19	25	0	100
Tamil Nadu	18	21	22	28	11	100
All-India	**23**	**25**	**24**	**25**	**3**	**100**

Source: Reliance Foundation – NCAER Survey 2014.

G. ESSO-NCMRWF-IMD forecast required at most nine days in advance

Farmers were asked for their ideal estimates on the number of days by which information on monsoon and temperature should be provided for their cultivation activities. Their responses show that the maximum is nine days for advance information (Table I.3.11).

Table I.3.11: Field survey perceptions for forecasting information

Operations stage	Average number of days before which temperature information is needed	Average number of days before which monsoon information is needed	Opportunity cost of not receiving information	
			Increased losses (% reporting cases)	Income reduction (% reporting cases)
Drought Area, no rains	9	8	44	26
Fertiliser Application	5	4	56	19
Flood Region, excess	6	5	43	25
Harvesting	7	6	32	41
Land Preparation	6	6	53	20
Post-Harvest Stocking	5	5	21	49
Scheduling Irrigation	5	5	39	27
Sowing	6	4	32	44
Spraying Pesticides	6	4	47	24
Vaccinating Cattle an	8	6	20	38
Total	**6**	**5**	**39**	**32**

Source: Reliance Foundation – NCAER Survey 2014.

Chapter I.4 Potential Economic Benefits on Increased Reliability & Accuracy of ESSO-NCMRWF-IMD Weather Prediction Systems

A. Macro Approach

Indian agriculture has been performing better since 2004–05. In a seminal article, Deokar and Shetty[1] attribute the growth to policy initiatives since 2004–05. However an in-depth analysis reported in the Economic Section of the Twelfth Five-Year Plan by the Planning Commission (2013) reveals that the agricultural growth of rain-fed areas has contributed to the renewed dynamism. This can be attributed to the increased reliability and accuracy of the numerical weather prediction systems of the ESSO-NCMRWF that are disseminated roughly three to ten days in advance through the IMD to the farming community, which go a long way towards mitigating the risks associated with rain-fed farming. Of course, policy initiatives play a catalytic role. However, if the growth dynamism can be attributed to growth in rain-fed areas, then we can associate this phenomenon with the increased reliability, accuracy and awareness of weather prediction systems by the farming community.

There is a general impression that the agricultural sector has not been doing well. Several articles provide anecdotes on fluctuating rainfall, poor development of irrigation, groundwater depletion, the vast number of small and marginal farmers in the sector, a sharp decline in productivity in high-irrigated areas such as Punjab, Haryana and Western Uttar Pradesh, the absence of a second green revolution in these high-irrigated areas to arrest productivity decline, etc. However, these remain anecdote-based analyses or opinions not backed by data analysis.

We initially analyse whether the available data indicate that agricultural growth has accelerated after 2005–06. Several experts argue that this could have been due to policy initiatives such as increased allocation to the sector since 2005, the introduction of the National Horticulture Mission, reforms in agricultural extension programmes initiated in 2005–06 and the Frontier Application Research in Agriculture, National Agricultural Innovation Project (initiated during July 2006). These policy initiatives play a major role; however, if the growth dynamism emanated from low-

[1]Growth in Indian Agriculture- Responding to Policy Initiatives since 2004-05, *Economic and Political Weekly,* June 2014 Vol XLIX,26 & 27

irrigated, low-productivity areas, then the growth dynamism cannot be attributed merely to these policy initiatives that are expected to catalyse growth in both irrigated and rain-fed farm areas.

Table I.4.1 indicates the gross value added for the agriculture, forestry and fishing sector by year. For the decade from 1994–95 through 2004–05, the average annual growth rate for agriculture and allied sectors was 2.4%, but it jumped to 4% during the period from 2005–06 to 2013–14. The trend is similar for the agriculture sector; the Y-o-Y growth rate averaged 2.7% for the decade 1994–95 through 2004–05 and 4% for the subsequent period.

Table I.4.1: Agricultural growth in 1994–95 through 2004–05 & 2004–05 to 2013–14

Year	Agriculture, Forestry & Fishing	Y-o-Y Growth	Agriculture	Y-o-Y Growth
1994–95	450,258		379,959	
1995–96	447,127	–0.7	376,243	–1.0
1996–97	491,484	9.9	415,377	10.4
1997–98	478,933	–2.6	403,030	–3.0
1998–99	509,203	6.3	431,719	7.1
1999–00	522,795	2.7	442,113	2.4
2000–01	522,755	0	439,432	–0.6
2001–02	554,157	6	467,815	6.5
2002–03	517,559	–6.6	429,752	–8.1
2003–04	564,391	9	476,324	10.8
2004–05	565,426	0.2	476,634	0.1
Period 1: 1994–95 to 2004–05		**2.4**		**2.7**
2005–06	594,487	5.1	502,996	5.5
2006–07	619,190	4.2	523,745	4.1
2007–08	655,080	5.8	556,956	6.3
2008–09	655,689	0.1	555,442	–0.3
2009–10	660,987	0.8	557,715	0.4
2010–11	717,814	8.6	610,905	9.5
2011–12	753,832	5	643,543	5.3
2012–13	764,510	1.4	649,424	0.9
2013–14	800,548	4.7		
Period 2: 2005–06 to 2013–14		**4**		**4**

Source: National Accounts Statistics 2014, Central Statistics Office.

Not only the gross value added, but also the Kharif, Rabi and total foodgrain production increased substantially during the second period. During the first period, food grain production increased

by merely 5 million tonnes during 2004–05 over the production in 1994–95 (3-period Moving Averaged Production); during the second period, roughly 41 million tonnes were added to food grain production during 2012–13 over the 2005–06 production level. (Table I.4.2)

Table I.4.2: Kharif, Rabi and total food grain production—3-year moving average

Year	Kharif Food grain	Average#	Growth (in %)	Rabi Food grain	Average#	Growth (in %)	Total Food grain	Average#	Growth (in %)
1994–95	101.1		-	90.4	-		191.5	-	
1995–96	95.1	100.0	–5.9	85.3	90.4	–5.7	180.4	190.4	–5.8
1996–97	103.8	100.2	9.3	95.5	90.5	12.0	199.3	190.7	10.5
1997–98	101.6	102.8	–2.3	90.7	95.6	–5.1	192.3	198.4	–3.6
1998–99	102.9	103.3	1.3	100.7	98.6	11.0	203.6	201.9	5.9
1999–2000	105.5	103.5	2.5	104.3	99.9	3.6	209.8	203.4	3.0
2000–01	102.1	106.6	–3.2	94.7	99.9	–9.2	196.8	206.5	–6.2
2001–02	112.1	100.5	9.8	100.8	94.4	6.4	212.9	194.8	8.1
2002–03	87.2	105.4	–22.2	87.6	94.8	–13.1	174.8	200.3	–17.9
2003–04	117.0	102.5	34.1	96.2	92.9	9.9	213.2	195.4	22.0
2004–05	103.3	110.1	–11.7	95.1	96.7	–1.2	198.4	206.7	–7
2005–06	109.9	107.9	6.3	98.7	100.2	3.9	208.6	208.1	5.2
2006–07	110.6	113.8	0.6	106.7	105.1	8.1	217.3	218.9	4.2
2007–08	120.9	116.6	9.4	109.8	111.0	2.9	230.8	227.5	6.2
2008–09	118.1	114.4	–2.3	116.3	113.4	5.9	234.5	227.8	1.6
2009–10	103.9	114.3	–12	114.2	118.0	–1.9	218.1	232.4	–7
2010–11	120.8	118.7	16.3	123.6	121.9	8.3	244.5	240.6	12.1
2011–12	131.3	126.7	8.6	128.0	126.9	3.6	259.3	253.6	6.0
2012–13	128.1	129.6	–2.4	129.1	130.7	0.8	257.1	260.3	–0.8
2013–14	129.4		1.0	135.0		4.6	264.4		2.8

Source: Ministry of Agriculture, Agriculture Statistics Division, DES.

Irrigation and Productivity Status of States and Recent Growth in Agriculture Output

Now, we refer to the analysis in the Economic Section of the Twelfth Five-Year Plan (2013). In this section, states were classified by the irrigation status. Three levels of irrigation status were created: High, Medium and Low. The states were also classified by their productivity status and ranked on three levels of productivity status: High, Medium and Low.

The high-performing states in terms of annual agricultural growth exceeding 5 per cent were separated from the others through an analysis of the performance of 27 states. Their irrigation and productivity status was super-imposed on these high-performing states, which revealed that the renewed growth dynamism evolved from rain-fed areas.

Table I.4.3: Irrigation and productivity status of states and their recent growth in agriculture output*

High	% growth	Medium	% growth	Low	% growth
I Irrigation Status of (27) States#					
Haryana	4.2	Andhra Pradesh	5.0	Assam	4.1
Punjab	1.8	Arunachal Pradesh	5.0	North East	5.9
Uttar Pradesh	2.8	Bihar	3.3	Manipur	3.3
West Bengal	2.6	Gujarat	5.5	Meghalaya	5.7
		Jammu and Kashmir	0.7	Mizoram	2.5
		Madhya Pradesh	4.4	Nagaland	7.3
		Odisha	3.1	Chhattisgarh	1.5
		Sikkim	3.4	Himachal Pradesh	8.0
		Tamil Nadu	4.6	Jharkhand	5.1
		Tripura	5.7	Karnataka	–0.2
				Kerala	5.3
				Maharashtra	5.5
				Rajasthan	2.0
				Uttarakhand	
II Productivity Status of (27) States#					
Tripura	5.7	Andhra Pradesh	5.0	Rajasthan	5.5
West Bengal	2.6	Arunachal Pradesh	5.0	Meghalaya	3.3
Kerala	–0.2	Bihar	3.3	Madhya Pradesh	4.4
Himachal Pradesh	1.5	Assam	4.1	Chhattisgarh	7.3
Punjab	1.8	Manipur	5.9	Maharashtra	5.3
Jammu & Kashmir	0.7	Mizoram	5.7	Odisha	3.1
Haryana	4.2	Nagaland	2.5	Jharkhand	8.0
		Sikkim	3.4	Karnataka	5.1
		Tamil Nadu	4.6	Gujarat	5.5
		Uttar Pradesh	2.8		
		Uttarakhand	2.0		

Source: Planning Commission (2013): Twelfth Five-Year Plan (2012–17), Economic Sectors, Vol II (p.4), Government of India.

Table I.4.4: Agricultural growth performance of Indian states analysed to identify best performing states

Best performing states (agriculture growth rate > 5% p.a.)			
Low irrigation and low productivity	**Low irrigation and medium productivity**	**Low irrigation and high productivity**	**Medium irrigation and medium productivity**
Jharkhand	Manipur	Tripura	Andhra Pradesh
Chhattisgarh	Mizoram		
Rajasthan			
Gujarat			
Maharashtra			
Karnataka			

Table I-4.4 shows that low irrigated and low productivity areas have accounted for the renewed dynamism in agricultural growth; in other words, the macro approach confirms that the renewed dynamism is due to accelerated agricultural growth in rain-fed areas.

To quote the Planning Commission (2013)

> "The growth acceleration since 2005 has therefore been much stronger in states with lower productivity and less irrigation. This suggests that the strategy may be correcting the past relative neglect which caused rainfed farming covering about 60% of arable land to perform well below potential."

We conjecture that the increased reliability, accuracy and timeliness of numerical weather prediction systems that aid cultivation in rain-fed areas have also been a principal reason for the acceleration in growth in rain-fed areas.

B. Micro- approach

To carry out an analysis using the micro-approach, we obtained unit-level agricultural household survey data (agricultural year July 2012–June 2013) from the NSSO in order to map production, area and net revenue from cultivation for around 150 crops at the state level as well as at the all-India level.

On this detailed data, we superimposed the perceptions of farmers on the net profit from cultivation, crop-wise, that can be attributed to ESSO-NCMRWF- IMD weather prediction systems. This provided nation-wide potential economic benefits that can be attributed to increased reliability and accuracy of the ESSO-NCMRWF-IMD weather prediction systems. The potential

economic benefits can be attributed to the increased robustness of numerical weather prediction systems developed by ESSO-NCMRWF, while the actual economic benefits realised would depend on the IMD's effectiveness in raising the awareness of the farming community and disseminating weather forecasts in a timely manner by partnering with NGOs and corporates.

The crop-wise details on area cultivated, physical quantity produced, value of products and by-products produced for the agriculture year July 2012 to June 2013, net profit from cultivation and the quantum of net profit that can be attributed to the ESSO-NCMRWF-IMD are shown in various tables following this section.

Of around 147 crops cultivated, 10 per cent account for 80 per cent of net profit accumulation (Table I.4.5) due to the use of ESSO-NCMRWF-IMD weather information and 20 per cent account for 90 per cent of net profit accumulation due to the use of these systems.

Table I.4.5:Percent of profit attributed to weather information

Crop	Net Profit from crop cultivation	Profit due to weather information as % to Net Profit	Net profit due to weather information	Crop-wise % share of net profit due to weather information in total net profit due to weather information
Wheat	55,163	25%	13,791	18.67%
Paddy	90,353	15%	13,553	18.35%
Sugarcane	33,575	25%	8,394	11.37%
Cotton	25,978	25%	6,494	8.79%
Soya bean	13,922	25%	3,480	4.71%
Maize	10,062	25%	2,515	3.41%
Gram	7,539	25%	1,885	2.55%
Rapeseed & Mustard	7,491	25%	1,873	2.54%
Other Non-Food Crops	5,621	25%	1,405	1.90%
Groundnut	5,260	25%	1,315	1.78%
Potato	5,055	25%	1,264	1.71%
Jowar	4,349	25%	1,087	1.47%
Bajra	4,252	25%	1,063	1.44%
Other Fodder Crops	4,084	25%	1,021	1.38%
Betel nuts (Areca nuts)	3,497	25%	874	1.18%
Rubber	3,126	25%	782	1.06%
Tur (Arhar)	3,046	25%	762	1.03%

Chillies	3,038	25%	759	1.03%
Apple	2,805	25%	701	0.95%
Banana	2,604	25%	651	0.88%
Tomato	2,140	25%	535	0.72%
Coconut	2,136	25%	534	0.72%
Guar	1,991	25%	498	0.67%
Tea	1,946	25%	487	0.66%
Urad	1,923	25%	481	0.65%
Onion	1,864	25%	466	0.63%
Other crops	28,800	25%	7,183	9.73%
All Crops	331,855	25%	73,852	100.00%

Source: NCAER computations based on NSSSO 2014 unit level data

1. Wheat, paddy, sugarcane and cotton are four principal crops that have the potential to use the weather prediction information of the ESSO-NCMRWF-IMD to generate an annual economic profit of Rs 42,000 crore.

2. The social discount rate used to discount annual economic benefits is 12%; the present value of an annuity of Re 1 per year for 25 years is 7.8451. This implies that the present value of gross economic benefits due to use of ESSO-NCMRWF-IMD forecast can potentially be Rs 3.3 trillion (Rs 330,000 crore) over the useful life.

3. Gross benefits need to be compared against investments made in the ESSO-NCMRWF-IMD to obtain net economic benefits.

Table I.4.6: Gross investments in ESSO-NCMRWF-history

HPC Resources					
Year	**2002**	**2006**	**2010**	**2012**	**2015**
HPC details	CRAY-SV1	CRAY-X1E	IBM-P6 (24 TFlops)	IBM-P6 (24 TFlops)	IBM iDataplex (350 TFlops)
Cost of Installation	9 crore	19 crore	35 crore		76 crore
Cost of Maintenance	1.47 crore per annum	1.76 crore per annum	1.8 crore per annum		
Support Infrastructure	50 lakh	1 crore	12 crore		26 crore
National Knowledge Network				5,990 crore/1,500 institutions	
Resolution of the AGCM	T80L18 150 km	T254L64 50 km	T382L64 35 km	T574L64 22 km	N768L70 17km
ESSO-NCMRWF: Manpower Resources					
Scientific & Technical Strength	30	30	40	50	62
Expenditure on account of salary	Rs 3.3 crore	Rs 3.6 crore	Rs 3.9 crore	Rs 4.2 crore	Rs 6.0 crore
Knowledge upgrading cost *	Rs 0.25 crore	Rs 0.25 crore	Rs 0.25 crore	Rs 0.25 crore	Rs 0.25 crore
ESSO-NCMRWF: Other Resources					
Contribution to WMO (approx. 1 crore/annum)					
Contribution to Monsoon desk (NCEP)/UKMO (approx. 1.5 crore/annum)					

*Note: * Approximate cost of international /national training*

Source: ESSO-NCMRWF-Authors' calculation

Table I.4.7: Future value of ESSO-NCMRWF past investments in 2014 base year

S No.	Year	Compounding factors	Cost of Installation	Cost of Maintenance	Support Infrastructure	National Knowledge Network	Expenditure on account of salary	Knowledge upgrading cost *	Contribution to WMO (approx. 1 / annum)	Contribution to Monsoon desk (NCEP)/UKMO (approx. 1.5 / annum)
1	2002	4.363	9.00	1.47	0.50	0.00	3.30	0.25	1.00	0
2	2003	3.896	0.00	1.47	0.00	0.00	3.30	0.25	1.00	0
3	2004	3.479	0.00	1.47	0.00	0.00	3.30	0.25	1.00	0
4	2005	3.106	0.00	1.47	0.00	0.00	3.30	0.25	1.00	0
5	2006	2.773	19.00	1.76	1.00	0.00	3.60	0.25	1.00	0
6	2007	2.476	0.00	1.76	0.00	0.00	3.60	0.25	1.00	0
7	2008	2.211	0.00	1.76	0.00	0.00	3.60	0.25	1.00	0
8	2009	1.974	0.00	1.76	0.00	0.00	3.60	0.25	1.00	0
9	2010	1.762	35.00	1.80	12.00	0.00	3.90	0.25	1.00	1.50
10	2011	1.574	0.00	1.80	0.00	0.00	3.90	0.25	1.00	1.50
11	2012	1.405	0.00	1.80	0.00	4.00	4.20	0.25	1.00	1.50
12	2013	1.254	0.00	1.80	0.00	0.00	4.20	0.25	1.00	1.50
13	2014	1.120	50.00	1.80	26.00	0.00	6.00	0.25	1.00	1.50
Future Value (Compounded value of past investments in HPC and Manpower resources, including supporting infrastructure and knowledge maintenance in Rs crore) Total future value in 2014 of past investments Rs 520 crore			209.64	51.23	55.22	5.62	113.84	7.85	31.39	10.67

Source: ESSO-NCMRWF-Authors' calculation

1. The future value of past investments in ESSO-NCMRWF, including the investments in knowledge networks, in 2014 base year prices work out to around Rs 485 crore only. This is insignificant when compared to the order of economic benefits is in trillions; any investments made to increase accuracy or obtain a finer resolution need to be welcomed.

2. The top 14 principal crops (from the top 10 per cent of crops surveyed) can use weather information and realise around Rs 60,000 crore economic profits annually. The top 28 principal crops (from the top 20 per cent of crops surveyed) have the potential to realise an annual

economic benefit of Rs 67,000 crore. The present value of economic benefits in the former case works out to Rs 4.7 trillion, while in the latter case it works out to Rs 5.2 trillion. The economic benefits to be realised are enormous; in comparison, the investments to obtain finer resolutions and improvement of accuracy are tiny.

Chapter I.5 Future Directions for ESSO-NCMRWF: Location-based forecasts for power utilities that Generate Renewable Energy

The total installed generation capacity as on date is 245,000 MW of which 10 per cent is renewable. Renewable energy is completely weather dependent. The ESSO-NCMRWF provides region-wise forecasts for wind speed, wind direction, temperature, humidity and pressure at a horizontal resolution of 25 km. Updates are provided every 12 hours. Within six months, finer resolution of forecasts (4 km), will be available. Updates on forecasts will be available at 12-hour intervals. Efforts are on to provide forecasts of cloud cover to enable forecasts of power generation from solar plants.

Forecasts of wind power generation need to be provided at one-hour intervals to the central grid authority with an accuracy of +/– 30% to avoid penalties. Norms are being evolved for such penalties for supply to the grid from renewable energy utilities. For instance, Tamil Nadu has a generating capacity of 12,000 MW, of which the wind power component is 7,000 MW. The state grid is not able to absorb more than 3,500 MW of cheaper wind power due to uncertainties.

States with excellent wind power potential are Tamil Nadu, Gujarat and Rajasthan. States with good wind power potential are Karnataka, Maharashtra and Madhya Pradesh. States with excellent solar power potential are Gujarat and Rajasthan.

Tax benefits available for renewable vary across states, from 80% accelerated depreciation benefits in the first year to tax holidays. Solar capacity will be around 100,000 MW by 2022; the cost of wind power is the lowest to date (around Rs. 4 KWH) and wind turbines with 2.1 to 2.3 MW capacities are being added in place of 350 KW wind turbines. Solar power generation, currently in the range of Rs 6 to 8 per KWH, is likely to almost match thermal generation costs soon.

Table I.5.1: Power generation options December 2014

Parameters	Wind Turbine	Solar Power	Hydro	Thermal Generation	DG set
Capital cost (in Cr/MW)	6	6.5 to 8	8 to 12	4.5	
Gestation Period	6 months	6 months	7 to 8 years	2 to 3 years	
Power Cost	**Rs 3.5 to 4/ unit**	**Rs 6 to 8/ unit. Started at Rs 18/unit and came down drastically**	**Rs 5/unit**	**Rs 3 to 4.5/ unit**	**Rs 11 to 14/unit**
Carbon foot-prints	Nil	Nil	Nil	Significant	Significant
Types of benefits for renewable (state-wise applicable)	**Accelerated depreciation 80% in first year, tax holidays in some states**				
Total Generation Capacity	23,000 MW	300 MW	Total hydro, thermal and renewable 2,45,000 MW	Total hydro, thermal and renewable 2,45,000 MW	-

Source: Compiled by Venkatesan, based on discussions with the National Centre for Medium Range Weather Forecasting (NCMWRF), Mani Karan Power (Trading), Mani Karan Solar and Wind Power Forecasting, NextGen Financial Solutions Pvt Ltd.

India consumed 1.12 billion MWH during 2012 (source MOSPI); assuming the renewable energy consumption at 5 per cent of total electricity energy consumption, the carbon footprint saved would be around 0.0056 billion MWH. Since 1 MGH replacement by renewable energy can be equated to a saving of 1 ton of carbon-dioxide or 1 Certified Emission Reduction, it can be valued at around €6 or at Rs 400 (exchange rate 1 Euro = Rs 66.52 as on 12 March, 2015). The savings would thus amount to Rs 22 billion or Rs 2,200 crore per year. If the renewable energy replacement to the extent of 10 per cent is achieved, the savings would be Rs 4,400 crore per year.

Saving over the useful life due to carbon credit earned in the farmer case at 12 per cent discount rate would work out to Rs 17,260 crore; in the latter case when 10 per cent of renewable energy replaces coal energy in the energy mix economic benefits over the useful life would total to Rs 34,500 crore.

Certainly, location based forecasts for renewable energy generating utilities to enable them to supple grid seems likely to be one of ESSO-NCMRWF's key future objectives in the near future.

Chapter II ESSO-INCOIS and its Economic Benefits

Chapter II.1 Importance and Performance of the Indian Marine Fisheries Sector

The marine fisheries sector plays a key role in the socio-economic development of India for four main reasons:

1. Promoting fisheries production is necessary for food security and nutritional security.
2. Foreign exchange earnings from exports of fisheries products at US$ 3.5 billion, which is roughly 3 per cent of overall exports, is significant.
3. Expansion of fisheries sector is twice as effective as expansion of non-agriculture sectors in removing poverty.
4. The fisheries sector has emerged as an important sector for generating employment.

Global development experiences, especially from the BRIC countries, reveals that one percentage point growth in agriculture and allied sectors (fisheries and forestry) is at least two to three times more effective in reducing poverty than the same magnitude of growth emanating from the non-agricultural sector.

A. ESSO-INCOIS and the Marine Fisheries Sector

The Ministry of Earth Sciences through its unit, the Indian National Centre for Ocean Information Services, plays a crucial role in the socio-economic development of the marine fisheries sector. ESSO-INCOIS provides Potential Fishing Zone advisories, Indian Early Tsunami Warnings, Ocean state Forecasts, Ocean Modelling and Data and Web Services Management.

Marine and inland fisheries and aquaculture are the main components of the fisheries sector in India. In recent years, mariculture or sea far minghas been gaining popularity and a couple of inland shell fish species and sea weeds are now being farmed. Ornamental fish farming, although an on-food activity also has a promising future and is likely to contribute to the over all growth of the fisheries sector in the coming years in terms of foreign exchange earnings and additional livelihood opportunities for fishers.

B. Marine Fishery Sector Statistics

1. BPL Fishermen form two-third of traditional fishermen: Marine fisheries are the source of livelihood for around 0.9 million families in the coastal states of West Bengal, Odisha, Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Maharashtra and Gujarat as well as in the Union Territories of Puducherry and Daman & Diu. 'Below Poverty Level' fishermen form roughly two-third of traditional fishing families. This is the main reason why the development of 3,218 villages located along the coast of 6,068 kilometres in the coastal states and coastal Union Territories is a major agenda of the Government of India (Table II.1.1).

Table II.1.1: Socio-economic characteristics of fishing community by state

State/U.T.	Coastal length (km)	Landing centres	Fishing villages	Fishermen families	Traditional fishermen families	BPL families	Fisher folk population	Ratio BPL: Fishermen) as per cent of traditional fishermen	Total State Population	Fisher folks as per cent of Total State Population	Average family size
West Bengal	158	59	188*	76,981	53,532	48,870	380,138	91%	91,347,736	0.42%	4.94
Odisha	480	73	813	114,238	87,541	56,279	605,514	64%	41,947,358	1.44%	5.3
Andhra Pradesh	974	353	555	163,427	161,039	159,101	605,428	99%	49,386,799	1.23%	3.7
Tamil Nadu	1076	407	573	192,697	185,465	127,245	802,912	69%	72,138,958	1.11%	4.17
Puducherry	45	25	40	14,271	14,248	10,998	54,627	77%	1,244,464	4.39%	3.83
Kerala	590	187	222	118,937	116,321	65,459	610,165	56%	33,387,677	1.83%	5.13
Karnataka	300	96	144	30,713	28,533	23,624	167,429	83%	61,130,704	0.27%	5.45
Goa	104	33	39	2,189	2,147	489	10,545	23%	1,457,723	0.72%	4.82
Maharashtra	720	152	456	81,492	74,203	15,509	386,259	21%	112,372,972	0.34%	4.74
Gujarat	1600	121	247	62,231	59,469	15,784	336,181	27%	60,383,628	0.56%	5.4
Daman & Diu	21	5	11	7,374	7,181	333	40,016	5%	242,911	16.47%	5.43
Total	**6,068**	**1,511**	**3,288**	**864,550**	**789,679**	**523,691**	**3,999,214**	**66%**	**525,040,930**	**0.76%**	**4.63**

Source: Marine Fisheries Census 2010. Central Marine Fisheries Research Institute Kochi Ministry of Agriculture, Department of Animal Husbandry, Dairying & Fisheries

** Subsequent reference to villages actually means Gram Panchayat in West Bengal*

2. **One million active fishermen and 0.66 million in allied activities:** Roughly one million people are active fishers, accounting for around 60 per cent of the occupational profile of fisher folk. Roughly 0.66 million people are involved in allied fishing activities such as marketing fish, making and repairing nets, curing and processing fish, peeling, labourer and others (Table II.1.2).

Table II.1.2: Occupational profile of fisher folk'

State/U.T.	Active fisher-men	No. of members involved in allied fishing activities						Other than fishing	Total occupied	Active fisher-men as per cent of Total occupied
		Market-ing fish	Making/ Repair-ing nets	Curing/ Process-ing	Peeling	Labourer	Others			
West Bengal	95,283	7,820	18,419	2,543	1,532	16,177	785	3,632	146,191	65.2%
Odisha	162,411	32,637	17,872	8,492	2,200	27,707	753	8,138	260,210	62.4%
Andhra Pradesh	150,868	39,324	14,082	16,848	2,904	64,141	2,790	10,999	301,956	50.0%
Tamil Nadu	214,064	37,440	6,995	7,125	3,076	12,828	4,077	9,847	295,452	72.5%
Puduch-erry	12,209	3,832	390	179	41	1,219	349	1,271	19,490	62.6%
Kerala	145,396	20,418	3,368	5,677	9,817	14,391	736	10,693	210,496	69.1%
Karna-taka	40,756	14,867	1,790	1,416	1,058	13,938	1,208	4,786	79,819	51.1%
Goa	2,370	1,481	117	0	0	3	0	1,130	5,101	46.5%
Maha-rashtra	76,345	45,971	14,477	9,554	6,493	28,873	5,908	5,657	193,278	39.5%
Gujarat	82,901	17,975	8,153	1,596	4,550	18,758	762	4,222	138,917	59.7%
Daman & Diu	7,480	1,541	1,041	37	28	1,111	6	3,188	14,432	51.8%
Total	**990,083**	**223,306**	**86,704**	**53,467**	**31,699**	**199,146**	**17,374**	**63,563**	**1,665,342**	**59.5%**

Source: Marine Fisheries Census 2010, Central Marine Fisheries Research Institute Kochi Ministry of Agriculture, Department of Animal Husbandry, Dairying & Fisheries

3. **44% of fishers are unschooled and more than two-third have less than primary school education:** Roughly 44 per cent of fisher folk are 'unschooled' (illiterate), while around 70 per cent have either only a primary school education or are 'unschooled' (Table II.1.3).

Table II.1.3: Educational status of fisher folk

State/U.T.	Primary		Higher Secondary		Above Higher Secondary		Unschooled*		Total		Unschooled as per cent of Total			Unschooled and Primary
	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female
West Bengal	70,102	63,924	37,269	26,470	3,082	885	65,019	59,833	175,472	151,112	37.1%	39.0%	77.0%	81.9%
Odisha	88,860	79,386	49,467	36,223	12,550	5,829	120,493	120,747	271,370	242,185	44.4%	49.0%	77.1%	82.6%
Andhra Pradesh	52,880	47,117	39,571	30,016	12,101	5,370	176,868	181,554	281,420	264,057	62.8%	68.0%	81.6%	86.6%
Tamil Nadu	109,608	98,238	107,131	98,204	25,474	23,606	137,075	134,789	379,288	354,837	36.1%	38.0%	65.0%	65.7%
Pudu cherry	5,992	5,933	8,277	7,269	2,291	1,537	8,012	9,541	24,572	24,280	32.6%	39.3%	57.0%	63.7%
Kerala	93,580	88,601	95,764	90,482	16,171	17,662	77,226	75,354	282,741	272,099	27.3%	27.7%	60.4%	60.3%
Karna taka	21,984	20,828	22,492	18,274	8,217	6,205	26,536	27,435	79,229	72,742	33.5%	37.7%	61.2%	66.3%
Goa	1,429	1,452	2,445	1,945	621	473	548	819	5,043	4,689	10.9%	17.5%	39.2%	48.4%
Mahara shtra	51,006	53,391	68,723	51,535	12,235	8,808	50,040	59,438	182,004	173,172	27.5%	34.3%	55.5%	65.2%
Gujarat	35,427	30,906	32,174	23,266	4,157	2,045	81,517	83,600	153,275	139,817	53.2%	59.8%	76.3%	81.9%
Daman & Diu	5,662	5,025	6,470	5,459	1,086	522	4,761	6,189	17,979	17,195	26.5%	36.0%	58.0%	65.2%
Total	**536,530**	**494,801**	**469,783**	**389,143**	**97,985**	**72,942**	**748,095**	**759,299**	**1,852,393**	**1,716,185**	**40.4%**	**44.2%**	**69.3%**	**73.1%**

*Note: *Children below 5 years excluded*

Source: Marine Fisheries Census 2010, Central Marine Fisheries Research Institute Kochi Ministry of Agriculture, Department of Animal Husbandry, Dairying & Fisheries

4. **Active fishers are predominantly male; in allied activities, fishers are predominantly female:** Gender-wise, fishing and allied activities show an interesting pattern of occupation. Females are occupied to the extent of 67 per cent in allied fishing activities that supplement the activities of 'active fishermen'.

5. **Infrastructure inadequacy in marine fishing villages:** An analysis of infrastructure facilities across coastal States and UTs indicates that out of 3,268 fishing villages only around 58 per cent have a bus stand, 27 per cent have hospitals, a mere 15 per cent have police stations, 40 per cent have post offices, 23 per cent have Internet connectivity, 67 per cent have community centres and 88 per cent have access to electricity. However, villages have more than adequate access to mobile phone facilities as well as access to co-operative societies. About 91 per cent of the villages have mobile phone coverage and about 1.59 co-operative societies are set up per village and thus ESSO-INCOIS efforts on development of region would give a fillip to infrastructure creation.

Table II.1.4: Infrastructure - Housing & Education (in the villages)

State/U.T.	No. of villages	No. of families	Housing		Education				Kutcha house as per cent of Total houses
			Kutcha houses	Pucca houses	Primary	Secondary	College	Technical Institutions	
West Bengal	188	76,981	66,284	10,697	1,198	238	9	0	86%
Odisha	813	114,238	86,988	27,250	810	255	49	31	76%
Andhra Pradesh	555	163,427	48,427	115,000	571	99	9	9	30%
Tamil Nadu	573	192,697	45,062	147,635	502	149	23	14	23%
Puducherry	40	14,271	3,940	10,331	39	8	4	2	28%
Kerala	222	118,937	17,477	101,460	469	182	38	58	15%
Karnataka	144	30,713	3,757	26,956	721	188	63	12	12%
Goa	39	2,189	15	2,174	93	47	8	6	1%
Maharashtra	456	81,492	7,732	73,760	713	245	93	58	9%
Gujarat	247	62,231	17,312	44,919	626	190	32	14	28%
Daman & Diu	11	7,374	846	6,528	78	34	3	6	11%
Total	**3,288**	**864,550**	**297,840**	**566,710**	**5,820**	**1,635**	**331**	**210**	34%
Average no. of Educational institutions per village					1.77	0.50	0.10	0.06	

Source: Marine Fisheries Census 2010. Central Marine Fisheries Research Institute Kochi Ministry of Agriculture, Department of Animal Husbandry, Dairying & Fisheries

6. **Share in total GDP and agricultural GDP is not insignificant:** The marine fisheries GDP at current prices during 2012-13 was estimated at Rs 29,945 crore, which is roughly 0.33 per cent of total GDP or around 1.85 per cent of agriculture and allied sectors of which the fisheries sector is a component.

7. **Marine fisheries sector exports:** India is a tropical country with multi-species fishery in the marine sector. India's contribution in global fish production for the year 2009 was 5.43 per cent and India ranked second in contribution, following China. Marine fisheries exports have been growing at around 20 per cent during the period 2006-07 through 2012-13 as shown in Table II.1.5.

Table II.1.5: Exports of fishery products

Year	Quantity ('000 tonnes)	Value (in Rs crore)	Growth Rate
2006-07	612.64	8,363.52	
2007-08	541.70	7,620.92	13%
2008-09	602.83	8,607.94	17%
2009-10	678.43	10,048.53	28%
2010-11	813.09	12,901.47	29%
2011-12	862.02	16,597.23	14%
2012-13	928.21	18,856.26	

Source: Marine Fisheries Census 2010. Central Marine Fisheries Research Institute Kochi Ministry of Agriculture, Department of Animal Husbandry, Dairying & Fisheries

8. **Marine fisheries sector infrastructure:** The infrastructure at India's fishing harbours (FHs) and Fish Landing Centres (FLCs) is shown in Table II.1.6.

Table II.1.6: Fishing Harbours (FHs) and Fish Landing Centres (FLCs)

FH at major port	Minor FH		FLCs	
	Commissioned	Under construction	Commissioned	Under construction
7	50	25	180	16

Traditional crafts	Motorised Traditional crafts	Mechanised boats	Total
52,982	73,410	72,749	1,99,141

Source: Marine Fisheries Census 2010. Central Marine Fisheries Research Institute Kochi Ministry of Agriculture, Department of Animal Husbandry, Dairying & Fisheries

To summarise, the profile of India marine fisheries and its contribution to GDP and exports can be are given in Table II.1.7 and Table II.1.8

Table II.1.7: Profile of India marine fisheries

Component		Profile
Physical Component		
	Length of coastline	8,129 km
	Exclusive economic zone	2.02 million km2
	Continental shelf	0.50 million km2
	Inshore area (<50m depth)	0.18 million km2
	Fishing villages	3288
Human Component		
	Marine fishers population	4.0 million
	Active fishers population	0.99 million
	Fishermen families	0.86 million
Infrastructure Component		
	Landing centres	1,511
	Major fishing harbours	6
	Minor fishing harbours	27
	Mechanised vessels	72,559
	Motorised vessels	71,313
	Non-motorised vessels	50,618

Table II.1.8: Indian marine fisheries statistics

GDP Marine Fisheries at Current prices (2012-13)	Rs. 29,945 crore
GDP Marine Fisheries at Constant prices (2012-13)	Rs.18,590 crore
Export earnings	US$ 3.5 billion
Percentage in total exports	3%
Domestic markets	81% fresh; 5% frozen; 6% dry; 5% fish meal
Per capita fish consumption	2.58 kg (range 0.3 -39)
Share in GDP	0.33%
Share in agricultural GDP	1.85%

Source: National Accounts Statistics

C. Marine Fisheries Sector Performance

There is a general impression that the agricultural sector has not been doing well. The factors cited in the literature are fluctuating rainfall, poor development of irrigation, groundwater depletion, vast numbers of small ad marginal farmers unable to adopt modern techniques of farming, the absence of any sign of a second green revolution, sharp declines in productivity even in agriculturally rich regions like Punjab, Haryana and western Uttar Pradesh and reduced public investment. However Deokar and Shetty (EPW June 28, 2014) have traced improved performance in agriculture since 2004-05, which is discussed in Section 1 of this report.

Has a similar phenomenon occurred in the marine fisheries sector? We examine the issue by examining the performance of marine fishing production during two periods, namely, before and after the introduction of PFZ. PFZ was initiated as a major programme (mission mode) during 2000-2001, but it is only after 2005-06 that the intervention of the NGOs was enhanced along with greater use of ICT based dissemination tools

GDP growth and value of production in the marine fisheries sector: The average growth rate (Y-o-Y growth), which was a mere 1.9% during 1995-96 through 2012-013, has accelerated since 2005-06 (Table II.1.9) to an average annual growth rate of 3.9%.

Table II.1.9: Acceleration in marine fisheries GDP growth

Year	GDP-marine (at constant 2004-05 prices) (Rs. cr)	GDP-marine (at current prices) (Rs. cr)	Y-on-Y growth	Ratio of marine fisheries GDP to Total GDP (at constant prices)	Ratio of marine fisheries to Total GDP (at current prices)	Marine GDP to total agriculture (at constant 2004-05 prices)	Marine GDP to total agriculture (at current prices)
1992-93	10,090	3,501		0.70%	0.50%	2.42%	1.73%
1993-94	10,938	4,455	8%	0.72%	0.54%	2.54%	1.90%
1994-95	11,699	5,700	7%	0.72%	0.60%	2.60%	2.11%
1995-96	12,110	6,200	4%	0.70%	0.55%	2.71%	2.11%
1996-97	13,419	7,387	11%	0.72%	0.57%	2.73%	2.09%
1997-98	13,524	9,621	1%	0.69%	0.66%	2.82%	2.57%
1998-99	11,783	9,681	-13%	0.56%	0.58%	2.31%	2.25%
1999-00	12,578	9,660	7%	0.56%	0.52%	2.41%	2.12%
2000-01	13,631	11,166	8%	0.58%	0.56%	2.61%	2.42%
2001-02	13,653	11,800	0%	0.55%	0.54%	2.46%	2.37%
2002-03	14,453	13,251	6%	0.56%	0.57%	2.79%	2.73%
2003-04	14,524	13,297	0%	0.52%	0.51%	2.57%	2.44%
2004-05	13,790	13,790	-5%	0.46%	0.46%	2.44%	2.44%
2005-06	14,409	16,626	4%	0.44%	0.49%	2.42%	2.61%
2006-07	15,432	17,975	7%	0.43%	0.45%	2.49%	2.49%
2007-08	16,140	19,609	5%	0.41%	0.43%	2.46%	2.34%
2008-09	15,748	20,469	-2%	0.38%	0.39%	2.40%	2.17%
2009-10	15,930	22,036	1%	0.35%	0.36%	2.41%	2.03%
2010-11	16,811	24,545	6%	0.34%	0.34%	2.34%	1.86%
2011-12	18,656	28,685	11%	0.36%	0.34%	2.47%	1.91%
2012-13	18,590	29,945	0%	0.34%	0.32%	2.43%	1.82%
Average growth rate of 1995-96 to 2004-05			1.9%				
Average growth rate of 2005-06 to 2012-13			3.9%				

Source: National Accounts Statistics

Can this be considered a consequence of the PFZ? Realising the limitations of using traditional knowledge of fishing, ESSO-INCOIS developed Potential Fishing Zone (PFZ) advisory services during the early 2000s. The PFZ services are built on the traditional knowledge of fishers but are applied using satellite remote sensing techniques and geographical information systems. These tools help in understanding the distribution of fishery resources and locating potential fishing grounds by mapping the concentration of chlorophyll and sea surface temperature. Timely forecasts for potential fishing grounds help the fishermen optimise their fishing operations and achieve a higher catch per unit. By this means, PFZ has become highly useful in improving the value add[2] of the marine fishing sector.

This change may be attributed to PFZ advisory services, since this was the only policy initiative implemented in the fishing sector. Table II.1.9 presents the value of output, value added and operational costs for marine fishing and agriculture GDP. The data on value added has been taken from the official website of the Central Statistical Organisation.

To look at another dimension of the impact of the PFZ on marine fishing, the annual growth rates in the marine fishing sector's value added were plotted separately for two periods: from 1994-95 to 2004-05 and from 2005-06 onwards. We assume that the impact of PFZ on marine fishing is visible only after at least a few months and so we have taken 2005-06 as the cut-off year, which is one year after the PFZ was introduced to the fishing community through the intervention of NGOs.

[2] CSO provides value of output for both marine and inland fishing separately and 'Repairs, maintenance and other operational costs' collectively for both sectors. To arrive at value add of the two sectors, we segregated the Repairs, maintenance and other operational costs in proportion to the value of output of marine and inland fishing sectors to calculate the value add of the sectors by subtracting operational costs from the values of output.

Table II.1.10: Value of output and value added, growth rates for agriculture and fishing sectors, at 2004-05 prices

	Year	In Rs. crore				
		Inland fishing output	Marine fishing output	Repairs, maintenance and other operational costs	Value add of marine fishing	Agriculture GDP
Pre-PFZ period	1995-96	10,564	14,309	3,823	12,110	376,243
	1996-97	11,083	15,873	4,168	13,419	415,377
	1997-98	11,363	15,923	4,112	13,524	403,030
	1998-99	12,065	14,038	4,193	11,783	431,719
	1999-00	12,897	14,933	4,390	12,578	442,113
	2000-01	12,998	16,179	4,594	13,631	439,432
	2001-02	14,300	16,142	4,695	13,653	467,815
	2002-03	14,669	17,131	4,971	14,453	429,752
	2003-04	15,648	17,183	5,079	14,524	476,324
	2004-05	15,743	16,246	4,836	13,790	476,634
Post-PFZ period	2005-06	16,939	17,022	5,212	14,409	502,996
	2006-07	17,739	17,988	5,077	15,432	523,745
	2007-08	18,949	18,779	5,302	16,140	556,956
	2008-09	20,486	18,364	5,535	15,748	555,442
	2009-10	21,450	18,505	5,561	15,930	557,715
	2010-11	22,714	19,492	5,806	16,811	610,905
	2011-12	23,313	21,948	6,788	18,656	643,543
	2012-13	26,235	21,549	6,562	18,590	649,424

Source: National Accounts Statistics

In a recent study conducted by the M.S. Swaminathan Research Foundation (MSSRF), detailed interviews were conducted with fishermen from East Godavari and Krishna districts in Andhra Pradesh and Yanam district in the Union Territory of Puducherry. The respondents were fishermen from different age groups who own boats as well as labourers working for boat owners. The interviews show that information services such as PFZ have helped fishermen reduce uncertainty in terms of sustained fish catch and weather variability. The fishermen have been using the PFZ information effectively and they never return without a profit. They make regular use of PFZ information whenever it is disseminated by the MSSRF and the PFZ services enable a fisherman to get economic benefits. While the majority are very happy and satisfied with the services in helping to improve their lives and livelihood, some felt that if PFZ information could be provided for a short distance it would help small craft fishermen. There are also requests for training on diesel engine mechanisms and to arrange for GPS at subsidised rates.

The fishermen have been able to send their children to school and college without borrowing money. They are also able take care of the health of their family members without much difficulty. This is possible only because of the improvement in their economic condition due to the improved catch through the use of PFZ services.

Growth of mechanised marine fishing craft: Apart from the PFZ, the share of mechanised craft in total craft has shown an increase since 2005-06 as shown in Table II.1.11; PFZ advisories are effective and useful for mechanised craft. The overall trends in growth of fishing units during the past five decades indicate the possible phasing out of non-mechanised canoes at least in certain regions, which reflected a negative growth rate of 51 per cent between 2005 and 2010. The total marine fishing fleet has in fact declined from 238,772 in 2005 to 194,490 in 2010, which is a decline of 19 per cent. Between 2005 and 2010, the declines were 51 per cent for non-mechanised craft and 6 per cent for motorised craft, but mechanised boats alone registered an increase of 23 per cent, from 58,911 in 2005 to 72,559 in 2010. There is a shift towards mechanised fishing units by **fisher folk due to their higher mobility, stability and technical efficiency.** This increase in the number of mechanised boats may be further attributed to the assistance provided for the purchase of crafts by different government and non-government agencies including the tsunami rehabilitation measures.

Table II.1.11: Share of mechanised craft in total craft

Year	Mecha-nised	Motorised	Non-mechanised	Total Landings	Mechanised (per cent)	Motorised (per cent)	Non-mechanised (per cent)
1985	9.52	1.30	3.48	14.30	66.6%	9.1%	24.3%
1990	13.11	4.48	3.04	20.63	63.6%	21.7%	14.7%
1995	14.93	4.44	2.04	21.41	69.7%	20.7%	9.5%
2000	16.82	6.67	2.04	25.53	65.9%	26.1%	8.0%
2005	15.21	5.92	1.03	22.16	68.6%	26.7%	4.7%
2006	18.52	6.47	1.25	26.24	70.6%	24.7%	4.8%
2007	18.95	7.95	1.13	28.03	67.6%	28.4%	4.0%
2008	22.70	7.43	1.19	31.32	72.5%	23.7%	3.8%
2009	23.59	6.84	0.93	31.36	75.2%	21.8%	3.0%
2010	26.07	6.44	0.68	33.19	78.6%	19.4%	2.1%
2011	30.07	7.29	0.94	38.30	78.5%	19.0%	2.5%

Source: CMFRI. 2010. Marine Fisheries Census 2010 – Kerala. Central Marine Fisheries Research Institute Kochi (Indian Council of Agricultural Research, New Delhi), Government of India, Ministry of Agriculture, Department of Animal Husbandry, Dairying & Fisheries, KrishiBhavan, New Delhi, p. 201.

Fish production: Table II.1.12 confirms that fish production has also accelerated since 2005-06.

Table II.1.12: Fish production in India (1950-51 to 2010-2011)

Year	Fish Production ('000tonnes)		
	Marine	Inland	Total
1950-51	534	218	752
1955-56	596	243	839
1960-61	880	280	1,160
1965-66	824	507	1,331
1970-71	1,086	670	1,756
1973-74	1,210	748	1,958
1978-79	1,490	816	2,306
1979-80	1,492	848	2,340
1980-81	1,555	887	2,442
1981-82	1 ,445	999	2,444
1982-83	1,427	940	2,367
1983-84	1,519	987	2,506
1984-85	1,698	1,103	2,801
1985-86	1,716	1,160	2,876
1986-87	1,713	1,229	2,942
1987-88	1,658	1,301	2,959
1988-89	1,817	1,335	3,152
1989-90	2,275	1,402	3,677
1990-91	2,300	1,536	3,836
1991-92	2,447	1,710	4,157
1992-93	2,576	1,789	4,365
1993-94	2,649	1,995	4,644
1994-95	2,692	2,097	4,789
1995-96	2,707	2,242	4,949
1996-97	2,967	2,381	5,348
1997-98	2,950	2,438	5,388
1998-99	2,696	2,602	5,298
1999-00	2,852	2,823	5,675
2000-01	2,811	2,845	5,656
2001-02	2,830	3,126	5,956
2002-03	2,990	3,210	6,200
2003-04	2,941	3,458	6,399
2004-05	2,779	3,526	6,305
2005-06	2,816	3,756	6,572
2006-07	3,024	3,845	6,869
2007-08	2,920	4,207	7,127
2008-09	2,978	4,639	7,617
2009-10	3,104	4,894	7,998
2010-11	3,250	4,981	8,231
2011-12	3,372	5,294	8,666
2012-13	3,321	5,719	9,040
2013-14 (P)	3,443	6,136	9,579

Sources: (i)Department of Animal Husbandry, Dairying and Fisheries (2009), Handbook of Fisheries Statistics, 2008. Ministry of Agriculture, Government of India.
(ii)Department of Animal Husbandry, Dairying and Fisheries (2011), Annual Report, 2010-11. Ministry of Agriculture, Government of India.

Concluding Remarks:

The fisheries sector is a key player in the overall socio-economic development of India for four reasons:

- It promotes fisheries production for food security and nutritional security.
- The foreign exchange earnings from exports are significant.
- Expansion of the fisheries sector is twice as effective as expansion of other sectors in eliminating poverty.
- The fisheries sector has emerged as a sector with considerable importance for generating employment.

Thus, the efforts of ESSO-INCOIS in the identification of Potential Fishing Zones serves the 'basic needs' of the 'reference income group'.

Chapter II.2 ESSO-INCOIS's Ocean State Forecast (OSF) System and Potential Fishing Zone (PFZ) and the Marine Fisheries Sector

PFZ Advisory was the first service started by ESSO-INCOIS. It uses satellite technology for the forecast of PFZ information. Sea Surface Temperature (SST) and chlorophyll over the Arabian Sea and the Bay of Bengal retrieved from thermal infrared channels of NOAA-AVHRR and optical bands in IRS-P4 OCM/MODIS Aqua data are used to identify PFZs along the Indian coastline and island regimes. These timely scientific forecast advisories have proved to be very useful for fishermen engaged in pelagic fishing activities such as gill netting. It has to a great extent been found useful in reducing search time, thereby minimising fuel cost and human effort.

The activities that take place along the Indian coastline vary from traditional fishing to high-tech oil exploration. In order to support fishing activities and avoid any untoward incidents at sea, India has made inroads into an informed decision-making support system by providing forecasts on sea state conditions for saving life and property. There is an inherent economic benefit to users of the ocean state forecast information. During cyclones and other extreme situations, based on the forecast information, alerts are issued to the general public as well as to administrators of the coastal stretch under risk so that the population under threat is relocated to safer places. ESSO-INCOIS has also been setting a new trend of reduced fishing days, leading to reduced fuel consumption by identifying potential fishing zones. Each state of India provides a diesel subsidy and also has a quota system to ration the fuel for fishing, so as to avoid over-exploitation. They also monitor fishermen by requiring a fishing license so that they do not cross into international water territories.

Since August 2012, ESSO-INCOIS and Reliance Foundation Information Services (RFIS) have been working on the effective dissemination of OSF data so as to reach every fisherman in the country in his own language with his own co-ordinate details. As of March 2015, RFIS covered 30,000 fisher folk in 7 states in 25 coastal districts with ESSO-INCOIS data. Marine fisheries contribute to nutritional security as well as livelihood and income generation to fishers. The RFIS decided to provide decisive inputs on this set of livelihoods by entering into an MOU with the Indian National Centre for Ocean Information Services to provide Ocean State Forecast (OSF) and Potential Fishing Zone (PFZ).

The OSF provides fishermen with decision parameters for venturing into the sea and choosing a suitable craft. High wave alerts and cyclone alerts are provided on issue basis for disaster preparedness. It is a life-saving tool.

At present, ESSO-INCOIS provides forecasts of the following:

1. Height, direction and period (of both wind and swell waves)
2. Sea surface currents
3. Wind speed and direction
4. Sea surface temperature
5. Mixed Layer Depth (the well mixed upper layer of the sea)
6. Depth of the 20 degree isotherm (a measure of the depth of the thermocline)
7. Astronomical tides
8. Oil-spill trajectory

The benefits of OSF may be categorised as:

1. Decision-making for adding fishing days, increase in income and assured catch
2. Reducing the possible loss of assets such as boat, engine, net, fuel and others
3. Saving lives in the case of a high wave alert and all disaster forewarnings especially cyclones
4. Understanding the net type for marine species based on the sea state.

The RFIS has been contributing to the ESSO-INCOIS informationby interpreting the scientific data of wave height, wind speed, wind direction, latitude and longitude in layman's language and translating it into the regional languages. RFIS information is shared as mobile advisories to fisher folk on a one-to-one basis as well as through scrolls and bulletins on cable television on a broadcast basis.

Effectiveness of technology replacing traditional techniques: Use of OSF and PFZ

The traditional fisher folk of India imagine the sky to be a great compass and clock, with stars functioning as the moving hands of the clock, indicating the time at night and giving directions. The fisher folk have a keen visual sense of the distance between stars, and their positions, which are used to tell time and species-specific fish movement more or less accurately while they work at night under a clear sky.

The fisher folk believe that prize catches are greater during the waning moon, and lean during the waxing moon. Tracking Venus for the early morning departure or the late evening departure is a basic art. Fisher folk believe that the light emitted from the star Pleiades, which is 630 light-years from Earth, influences the movement of fish shoals. This traditional knowledge has been replaced with the Potential Fishing Zone and Ocean State Forecasts provided by ESSO-INCOIS.

Chapter II.3 Economic Benefits of ESSO-INCOIS's PFZ Advisories to the Fishing Communities

A macro-analysis of PFZ advisories on accelerating marine fisheries GDP growth rate provides a broad picture, in this section we conduct an economic cost–benefit analysis of providing PFZ advisories. This section provides an estimate of net economic benefits arising out of RFIS-ESSO-INCOIS interventions in the form of PFZ to fishers/boatmen. Besides, we also briefly outline the environmental and ecological effects of such interventions.

The analysis is based on the economic benefits realised by the fishing community in the fishing villages surveyed by the RFIS. RFIS-NCAER conducted an exclusive survey of the fishing community to assess the economic benefits. The survey covered boatmen (owners) as well as unskilled labour in these coastal villages in seven states in the year 2014. Net economic benefits of RFIS–ESSO-INCOIS interventions have been assessed as the additional economic benefits in the hands of boat owners, labourers and drivers during the post RFIS-ESSO-INCOIS intervention period over the earlier fishing practice methods period prior to PFZ interventions. Environmental benefits are outlined as the benefit due to a reduction in overall energy consumption due to lower specific energy consumption per unit catch. Ecological benefits are outlined as the net gain in the new eco-system that arises out of the provision of PFZ advisories. The overall gain is estimated as the cumulative of economic, environmental and ecological benefits.

1. Economic Benefits Assessed from Case studies on post-MSSRF-ESSO-INCOIS interventions in Tamil Nadu and Puducherry

ESSO-INCOIS (www.incois.gov.in) generates multi-lingual PFZ advisories every Monday, Wednesday and Friday and disseminates these to about 500 fish landing centres/fishing villages covering the entire coastline of India under 12 sectors, viz. Gujarat, Maharashtra, Karnataka, Goa, Kerala, South Tamil Nadu, North Tamil Nadu, South Andhra Pradesh, North Andhra Pradesh, Orissa, West Bengal, Lakshadweep Islands and Andaman & Nicobar Islands.

Table II.3.1: Improvements in accuracy

Details of Advisories	Level of per cent accuracy per Gilakalandi village fishers (%)
Potential Fishing Zone	70 to 80
Tuna Forecast	70 to 80
Ocean State Forecast (wave height, wind speed and direction)	80 To 90
Rainfall Information	NA
Cyclone and Tsunami Alert	Early Warnings

Source: MSSRF

The accuracy of PFZ is rated at 70-80 per cent while the OSF component in PFZ advisories was 80 -90 per cent accurate (Table II.3.1), while they acknowledged that these advisories have come to play a critical role in their lives; enables them to plan and make decisions regarding their fishing activity, while the PFZ advisory helps them deploy their nets in an appropriate location to catch fish resources.

The fishers value the OSF as they see it as lifesaving. According to them, it has considerably brought down the anxiety and uncertainties of their families during bad and uncertain weather conditions. Since they have access to OSF, they can plan their fishing activity accordingly; if the forecast is not conducive for venturing into the sea, the fishers stay back on shore and also take precautions to safeguard their fishing vessels and related gadgets. Thus, they are able to avoid loss of human life and damage to fishing gear. Fishermen value OSF advisories as well as the early warnings associated with PFZ advisories as 'vital' and 'life saving'.

A significant development that was witnessed in the post-MSSRF–ESSO-INCOIS intervention period was the adoption of gill netting fishing in place of the bottom trawling fishing method practiced earlier.

PFZ data was found to be very useful in surface fishing and yielded a good harvest of fish resources, such as tuna and other fish resources of high market value. Boat owners who were not comfortable with the idea of changing their fishing gear slowly started to convert their boats to gill netting one by one. By July 2013, when the survey was carried out, of 65 boats owned by 23 responders, 50 fishing vessels were converted; three new boats were newly constructed.

Cost Escalation Factor

Table II.3.2: Cost Escalation Factor

Capacity	Motorised Boats	Mechanised Boats
7 tonnes		6.0%
8 tonnes	10.0%	
10 tonnes		
12 tonnes	18.6%	
14 tonnes		
20 tonnes		4.2%
Average	14.3%	5.1%

Source: Reliance Foundation – NCAER Survey 2014

For the same capacity, for fishing craft acquired during different periods the cost escalation factors were assessed using semi-log regression. The average cost escalation figure for motorised craft works out to 14.3%, while for mechanised craft it is 5.1% (Table II.3.2).

Economy of Scale Factor

The Economy of Scale Factor uses the relationship:

$$\text{Capital Cost}_{\text{New Capacity}} = \text{Capital Cost}_{\text{Old Capacity}} * (\text{New Capacity/Old Capacity})_{\text{Economy of Scale Factor}}$$

The economy of scale factor was assessed at 0.85 from the data collected from the RFIS-NCAER survey of 2014. Basic data on 21 craft during the field survey are shown in the table II.3.3.

Table II.3.3: Basic data collated for 21 crafts pre and post –PFZ OSF- operations

Boat Type	Number of boats	Expenditure Total sum (Rs)		Capital cost escalated sum (Rs. lakh)		Sales realisation sum (Rs.)		Labour expenses sum (Rs.)		Driver expenses sum (Rs.)		Diesel expenses sum (Rs.)	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Traditional	5	1,351,000	1,303,600	8	8.167	10,180,600	11,250,200	25,000	25,000	0	0	6,000	5,250
Motorised	4	935,000	904,000	8	8.13	7,630,880	8,539,680	20,000	20,000	0	0	4,800	4,200
Mechanised	12	3,170,000	3,020,000	397	383.65	29,020,000	28,912,000	276,600	281,300	234,000	246,000	211,000	181,000
Total	21	5,456,000	5,227,600	412.947	399.947	46,831,480	48,701,880	321,600	326,300	234,000	246,000	221,800	190,450

Source: Reliance Foundation – NCAER Survey 2014

The basic data per craft by boat type was derived as under:

Table II.3.4: Basic data collated per boat

Boat Type	Number of boats (secondary statistics)	Expenditure Total (Rs)		Capital cost escalated (Rs.)		Sales realisation (Rs.)		Labour expenses (Rs.)		Driver expenses (Rs.)		Capital recovery/ boat		Diesel expenses sum (Rs.)	
		Before	After	Before	After	Before	After	Before	After	Before	After	Before	After	Before	After
Traditional	52,982	270,200	260,720	163,340	163,340	2,036,120	2,250,040	5,000	5,000	0	0	20,826	20,826	1,200	1,050
Motorised	73,410	233,750	226,000	203,250	203,250	1,907,720	2,134,920	5,000	5,000	0	0	25,914	25,914	1,200	1,050
Mechanised	72,749	264,167	251,667	3,305,417	3,197,083	2,418,333	2,409,333	23,050	23,442	19,500	20,500	421,441	407,628	17,583	15,083
Total	199,141	259,810	248,933	1,966,414	1,904,510	2,230,070	2,319,137	15,314	15,538	11,143	11,714	250,718	242,825	10,562	9,069

Source: Reliance Foundation – NCAER Survey 2014

Table II.3.5: Increase in GVA and additional profits to fishers due to PFZ

Boat Type	Additional Profit due to PFZ/OSF (Rs. crore)	GVA due to PFZ/OSF		Additional GVA due to PFZ/OSF	
		After	Before	Value (Rs crore)	%
Traditional	1,184	10,566	9,383	1,184	12.6%
Motorised	1,725	14,050	12,325	1,725	14.0%
Mechanised	126	16,016	15,981	36	0.2%
Total	3,034	40,633	37,689	2,944	7.8%

Source: Reliance Foundation – NCAER Survey 2014

2. Increase in GVA and additional profits to fishers due to PFZ

The economic analysis indicates that the real growth rate of gross value added in marine fisheries GDP can go up to 7.8 % (Table II.3.5) per annum from the current level of 3.9 per cent once the PFZ-OSF is operationalised uniformly across the country in all coastal areas.

It also indicates that the additional profit in the hands of fishers due to PFZ operations would be around Rs 3,000 crore, annuity. This annuity would amount to a present value of Rs 23,800 crore over a 25-year useful life. Since this is the reference income level, the economic benefit can be assumed to be Rs 23,800 crore as a result of the operationalisation of coupled atmospheric and ocean state forecasts. The gross investments in the PFZ and OSF departments of ESSO-INCOIS were a mere Rs 32 crore, arrived at as the future value of past investments at 12 per cent social discount rate.

3. Environmental analysis

Identification of PFZ results in saving diesel consumption since fishers now zero in on a particular area. The savings in diesel consumption result in a reduction in carbon dioxide emissions. A one litre saving in diesel consumption can reduce 2.63 kilograms of carbon dioxide emission. Since a reduction of 1 tonne of carbon dioxide mission is equivalent to 1 Certified Emission Reduction (CER), this can be valued in economic terms because such reductions are internationally traded. The environmental effect of savings in diesel consumption computed as carbon credit would work out to an annuity of Rs 36,200 crore or a present value of around Rs 2.84 trillion over the 25-year useful life, which is quite significant.

Table II.3.6 Carbon credit computations

Boat Type	Diesel Consumption (in crore litres)		Carbon dioxide emission reduction (in crore tonnes)			Carbon credits (in Rs. crore)
	Before	After	Before	After	Reduction	
Traditional	8,020	7,018	21	18	3	1,055
Motorised	15,397	13,473	40	35	5	2,025
Mechanised	221,567	190,065	583	500	83	33,141
Total	244,985	210,555	644	554	91	36,220

Source: Reliance Foundation – NCAER Survey 2014

4. Ecological benefits

The labourers and drivers acknowledged the beneficial effects of the PFZ and OSF advisors. According to them, PFZ advisories are quite accurate; it has become less complicated to reach locations with fish shoals and their family members are assured of additional consumption benefits. The provision of PFZ and OSF information makes the crew and their family feel secure.

Besides, the labourers' manual work has come down drastically, resulting in improved health and in an ability to spend more quality time with family members.

Chapter II.4 Benefits of ESSO-INCOIS's Ocean State Forecast to Different Users

A. Introduction

Over the past decade, an increasing emphasis has been laid on national ocean observing and forecast systems given India's large coastline of over 7500 kilometres. The Earth System Science Organisation - Indian National Centre for Ocean Information Services (ESSO-ESSO-INCOIS's) provides the Ocean State Forecast (OSF) to its intended beneficiaries which includes the Indian Navy and Indian Coast Guards in safety and rescue operations and oil spill tracking, offshore industries in oil and gas explorations and installations, maritime boards in managing ports and harbours, passenger and merchant ships for safe route tracking.

At present, the ESSO-INCOIS provides ocean state forecasts on:

1. Profiles of temperature, salinity and currents (global and Indian Ocean), sea surface height anomaly from ocean circulation forecast models
2. Ocean wave parameters (wave height and period) analysis and forecasts from global and regional wave models
3. Automated ocean state alerts from data assimilative ocean wave model
4. Real-time storm-surge forecasts
5. Satellite and model based global ocean vector winds products (speed and direction)
6. Oil- spill trajectory

While these OSF services and products are of the nature of public good and is provided widely and freely to a whole range of its potential users and beneficiaries, an attempt has been made to estimate the net benefits derived from these different users in terms of numeraire (uncommitted income in the hands of government).

The net economic benefits can be categorised as the sum of

i. Economic benefits (inputs and outputs valued at economic prices at the social discount rate)
ii. Environmental benefits (benefits accruing due to carbon-dioxide reduction benefits), as well as
iii. Ecological benefits (benefits due to "non" disturbance of the ecosystem or for the betterment of the existing ecosystems). The last component is location specific. Thus the overall net economic benefit will be location specific and not services/technology specific.

Thus, while a comprehensive cost and benefit analysis cannot be conducted due to the location specific nature of the benefits that accrue to the users. However, economic benefits computation definitely allows us to better comprehend the growing need to develop, and appreciate the economic value, of an accurate and reliable ocean state forecasting system. The estimates of economic benefits are based on our interviews with the agencies and industries' experts and varied data collated from these users. The methodology for estimation varies for each user based on the availability of limited information due to the involvement of sensitive users like the Indian Navy and Indian Coast Guard.

B. Estimation of benefits to users

I. Indian Navy

Since the first time use of ocean surface winds for circumnavigation voyage of Indian Navy sailing ship (INS Tarangini) in 2003, the Indian Navy has remained an extensive user of similar forecasts from the ESSO-INCOIS and ESSO-NCMRWF. The Indian Navy uses the four-day forecast data on winds, currents and swells to plan their operational activities. The generalised forecasting system on the ESSO-INCOIS website as well as the average first-day forecast, which is sent by mail, is also used for this purpose.

The Indian Navy has been using OSF and Tsunami alert systems for providing oceanographic forecast to various agencies including Defence Research and Development Organization (DRDO) during its missiles launching programmes, Strategic Force Command along with identifying safe and strategic positioning of naval ships and submarines and safety and rescue operations. Due to the national security threat concerns associated with the naval operations, much of the sensitive information is not available for dissemination in the public domain. Consequently, an alternative approach is used to estimate the net economic benefits accruing to the Navy due to the OSF.

With the available information, an attempt is made to find the number of instances of 'no mission go ahead', issued which were based on OSF and consequently, avoided infructuous expenditure. This avoided expenditure has been computed as net economic benefits. With reliable and accurate OSF, the missions of DRDO missions would have been deferred due to an adverse OSF. Such cost savings avoided due to 'no mission go ahead' can be considered as net benefits. The number of 'no mission go ahead' that were issued is then multiplied by the typical average of infructuous cost avoided in operations of a mission. It is assumed that the typical mission cost would include 2-3 missile carrying ships on voyage for 8-10 days with 30 personnel on board.

The Indian Navy was requested to provide such information through an examination of its logbooks for the last four and a half years[3] . Such an analysis revealed that five 'no go ahead mission' advisories were provided to the DRDO, Strategic Force Command and ships/submarines since 2013. Assuming that two ships belonging to IPV (New class) is used for 8-10 days for the mission, the capitation cost of ships works out to Rs. 832 crore (based on capitation fee of Rs. 46.24 crore per vessel per day). The personnel cost, assuming 30 personnel of various grades works to be mere Rs. 0.05 crores. So the total cost of a typical mission is approximately Rs. 832 crore. Since five 'no go ahead mission' advisories were given, the net benefits during 2013-2015 works out to be Rs. 4,161.9 crore. The annuity of avoided expenditure will be Rs. 2,080 crore. The present value of annuity for 25 years at 12 per cent social discount rate will be approximately Rs. 16,000 crore.

Further, no tsunami threat has played very important role in conduct of operations pertaining to the movement of ships and submarines in and out of the harbour resulting in saving of fuel amounting to lacs of rupees. We are unable to estimate the fuel savings due to non-availability of data.

While, the Indian Navy uses many other similar global platforms like ESSO-INCOIS's OSF, including the Ship Performance Optimization System (SPOS), BonVoyage System (BVS) amongst many others. Further, Naval Operations Data Processing & Analysing Centre (NODPAC) is a nodal agency in the Indian Navy, which collates Sub-surface, Surface Meteorological and upper atmospheric data and these datasets are utilised to produce customised oceanographic and meteorological products for Indian Naval users. In addition, this unit is also involved in generating OSF every 06 hours for 5 - 9 days.

ESSO-INCOIS's upper edge amongst these other available systems being its customized reports (especially for the Bay of Bengal area), security and strategic advantages associated with using a local system rather than a global system and also, the sole source of tsunami alerts and other earthquakes. ESSO-INCOIS was also appreciated for its very strong feedback mechanism and very accurate forecasts in the range of 70-75%.

NCAER also queried NODPAC which set up with an objective to support naval operations by providing the right Meteorology and Oceanography (METOC) information, in right format, in

[3] The ongoing term of the current chief of meteorological, oceanographic & environmental assessment unit, Visakhapatnam

right quantity and in right time to give a decisive edge to the fleet. Over the next two years the goal of the unit is to provide near real time, reliable OSF to the users at sea that is contemporary and user friendly using Geographic Information System (GIS) based applications.

NODPAC uses all the aforementioned services provided by ESSO-INCOIS except the astronomical tides and were asked whether the information provided can be considered as vital (cannot be replicated by NODPAC), essential (of crucial importance but can be replicated by NODPAC if need be) or desirable ("Others" that can be replicated by NODPAC). NODPAC responded that the ESSO-INCOIS services falls in the 'essential' category. NODPAC receives ESSO-INCOIS generated OSF every day and subsequently, uses these in support of planning naval operations and also validation of numerical models run at NODPAC.

Ocean surface currents and wave information helps in navigation, while mixed layer depth, sub-surface temperature and salinity profiles help in optimum exploitation of sensors on-board ships. The forecast accuracy of ESSO-INCOIS was rated as very accurate in the range of 60-80 per cent.

NODPAC opined that OSF information has improved the preparedness and readiness of naval operations by 70 per cent; preparedness can be broadly interpreted as increased usage of available infrastructure and skilled manpower of navy through regular research inputs from ESSO-INCOIS and NODPAC. ESSO-INCOIS's OSF products are regularly utilised at NODPAC to provide forecast for particular mission and also in conjunction with their own OSF products. Inter comparison model outputs help in improving the accuracy of the forecasts.

On being questioned about the need for additional services or improvement in existing delivery mechanism of ESSO-INCOIS, NODPAC suggested that following information and services can be useful for the NODPAC and the Indian Navy:

a) Direct access of insitu oceanographic data from various platforms such as Moored Buoy, Wave rider buoy, Drifters, AWS, HF Radar, Tide gauge, ARGO data, current Metre data and swell information.
b) Direct communication linkage between NODPAC and ESSO-INCOIS server through BSNL leased line with high bandwidth for better access of ESSO-INCOIS products.

II. Indian Coast Guard

The Indian Coast Guard (ICG) is mandated to protect the maritime interest and other national interest within the maritime zones including the offshore terminals, installations and structures, search and rescue operations for vessels and fishermen in distress, assisting in anti-smuggling operations and preventing and controlling maritime pollution. Infact, the ICG is the Central Coordinating Agency (CCA) for responding to all the marine oil spills in the Indian maritime zone and has been mandated to train, coordinate and exercise all stakeholders for any oil spill contingency in the Indian waters.

The Indian Coast Guard also uses the ESSO-INCOIS four-day forecast to plan their operational activities. During oil spill contingencies they use the Online Oil Spill Advisory system (OOSA). The generalised forecasting system on the ESSO-INCOIS website as well as the average first-day forecast, which is sent by mail, is also used for this purpose. The Indian Coast Guard uses the webmap services as well as the forecast along the ship tracks in planning their operations.

While, the OSF is used is in all the aforementioned subjects, an estimation of benefits accruing from safety and rescue operations is beyond the scope of this report given the intangible nature of such benefits.

However, an alternative approach to estimate the potential benefits that can be attributed to the Online Oil Spill Advisory (OOSA) system developed and launched (2014) by ESSO-INCOIS is attempted. OOSA generates a predicted trajectory after submitting the marine oil spill details, enhancing the efficacy of response by the ICG to such marine disasters.

During our meetings with the Indian Coast Guard, we were able to obtain the details of the capitation charges received from the polluters since 1982. The amount received from the polluter includes only the ICG response cost i.e. the actual economic cost incurred in the clean-up process. This cost does not include the ecological and environmental damages caused due to the oil spill. A comprehensive 'Natural Resource Damage Assessment (NRDA) process was also proposed by the ICG in order to ensure a well calibrated framework for an objective and cost-effective assessment of environment damages due to oil spills. It is acknowledged that estimating a total clean-up cost is determined by varied factors like amount of oil, type of oil and its persistence toxicity, location, weather, logistics amongst many others. Thus making it difficult to estimate a single figure for total clean-up cost per tonne including all the factors a rather difficult exercise and beyond the scope of this study. However, if we assume that the cost polluter pays has correspondence to the

damage caused by the oil spill then the average cost of oil spill cleaning up should cost around USD 1,000 per tonne as shown below:

Based on the data in the public domain, around 90 minor and major oil spills have occurred in the Indian water since 1982. We were able to obtain the amount received from the polluters for about 17 such incidences. Only economic cost has been considered for estimation of the clean-up cost because environment and ecological are expected to be location and context dependent. The total cost paid by polluters in 2015 prices for 15,211 tonne has been computed as Rs. 89.43 crore. The social discount rate of 12% has been used to compound the past prices in terms of 2015 prices. The per tonne cost paid by the polluter works out to Rs. 58,796 or USD 947 (Table II.4.1).

Table II.4.1: Oil Spill during 1982-2015 and amount paid by the polluters

Year of Spill	Location	Amount of Oil Spill (Tonne)	Type of Oil	Amount Received from the Polluter (In Rs lakhs)	Amount Received from the Polluter in 2015 prices (Rs Lakhs)	Rupee Cost per tonne in 2015 prices	Dollar Cost per tonne in 2015 prices*
1989	795 nm SW of Bombay	5,500	Diesel Oil	6.7	126.9	2,307	$37
1992	Madras Harbour	1,060	SKO	16.9	229.6	21,662	$349
1992	Bombay Harbour	300	FO	3.6	48.4	16,120	$260
1993	Bombay Harbour	110	Crude Oil	2.3	28.1	25,525	$411
1993	Bombay High	6,000	Crude Oil	224.9	2,721.4	45,357	$730
1994	Off Sacromento Pt.	1,600	Crude Oil	329.0	3,554.5	222,154	$3,577
1995	Off Dawarka, Gujarat	Not Assessed	FO	137.2	1,323.7		
1999	MulDawarka, Gujarat	500	FO	43.7	268.1	53,618	$863
2005	Off Goa	110	-	103.7	322.0	292,729	$4,713
2006	Off Porbandar	Not Assessed	-	8.4	23.3		
2006	Off Ratnagiri	Not Assessed	-	12.4	34.3		
2007	Off Jakhau, Gujarat	13.9	FO	49.1	121.6	874,901	$14,086
2010	Eastern side of KavarattiIsalnd	17.24	Oil	2.0	3.5	20,494	$330
2011	Bassein field of ONGC Ltd.	Not Assessed	-	41.1	64.7		
2011	Off Mumbai	Not Assessed	-	26.0	40.9		
2014	Kamonthe, Raigad, Maharashtra	Not Assessed	-	11.3	12.6		
2015	Off Kalkata Port	Not Assessed	-	20.1	20.1		
	Total	**15,211**		**1,038.4**	**8,943.6**	**58,796**	**$947**

Source: Indian Coast Guard.

Note: 1 INR = 0.016 USD , average of exchange rate between the period 1st June, 2014 to 30th May, 2015

Table II.4.2: Number and amount of oil spills (1988-2015)

Year	Amount of Oil Spill	No. of Spills
1988	1,000	1
1989	5,500	5
1990		1
1991	40,692	2
1992	2,360	4
1993	46,550	7
1994	3,013	5
1995	200	3
1996		
1997	280	5
1998	20	5
1999	500	1
2000	1	3
2001	1,305	2
2002		1
2003	4,445	4
2004	550	2
2005	2	3
2006		
2007		
2008		
2009	200	3
2010	825	6
2011	570	6
2012	24	3
2013	5	1
2014	58	3
2015		
Total	**108,100**	**76**

Source: Indian Coast Guard.

Table II.4.3: Present value of annuity paid by the polluters

Average amount spilled per year	4,004
Average number of spills per year	3
Average amount paid by polluter (Rs. per tonne)	58,796
Total likely annuity paid by the polluter (Rs. Crore)	23.5
PV of annuity @ 12% for 25 years (one rupee)	7.84
PV of annuity paid by polluters @ 12% SDR for 25 years useful life (Rs. Crore)	184.6

Source: Indian Coast Guard and authors' calculation.

Obviously, the polluter does not pay the Indian government even the clean-up economic cost in full. The PV of annuity of what polluter pays for an average annual oil spill of 4,000 tonnes, based on average oil spills incidents during the period 1988-2015, and would be Rs. 185 crore only (Table II.4.3).

The actual cost of cleaning up without considering environmental and ecological costs varies substantially across countries as shown in Table II.4.4.

Table II.4.4: Clean-up cost by countries

Country	Clean-up Cost (USD / tonne)
Malaysia	76,589.3
Japan	34,619.9
United States	25,614.6
Norway	23,118.1
South Korea	12,815.0
Denmark	11,180.4
Germany	10,702.0
Greece	8,530.3
Canada	6,508.1
Australia	5,991.3
Brazil	5,600.7
UK	3,082.8
France	2,301.6
Finland	2,115.3
Philippines	676.5
Spain	438.7
Singapore	390.6
Lithuania	78.1
Mozambique	6.1

Source: Proceedings of the 18th NOSDCP and Preparedness Meeting, 2013, ICG, Ministry of Defence

III. Offshore oil and gas industries

The ever-increasing energy demands has pushed the oil and gas exploration operations further offshore, resulting in a greater need for meteorological and oceanographic forecasts and near real time data. During the exploration stage, the data on positioning of its platforms needs inputs from the domestic satellite for strategic considerations and ESSO-INCOIS' OSF fills this vital need. Also, this is crucial to protect the fishermen straying on their unmanned platforms for their personal use and terrorist targeting their platforms. Besides this, oil spills due to corrosion in pipes needs to be tracked and removed. Such oil spills could be governed by under surface internal waves, which can travel distances much faster; tracking such internal waves and mitigating the damage due to oil spill is served by ESSO-INCOIS's OOSA(the oil spills clean-up cost were estimated in the previous section II).

In this section, we estimate the benefits of OSF for offshore industries producing crude oil and gas based on Oil and Natural Gas Corporation (ONGC) "Development Wells Drilling in the Offshore Block KG-DWN-98/2 KG Basin, Andhra Pradesh" project.

The ONGC uses the long-term met-ocean data for a particular location to decide on the suitability of rig locations and this is done on a case-by-case basis, supported by ESSO-INCOIS using archived data. It also uses the web map services to identify the general conditions at the location and the forecast along the ship track to plan the ship route. The ONGC has already taken information from ESSO-INCOIS regarding zones with strong wind potential in their western offshore field, Mumbai High, through a consultancy project from IOGPT, ONGC, and Mumbai. Collaborative in situ data collection from two of their platforms are being pursued to validate the wind assessment, which has already been done using climatological bias-corrected satellite data. Daily operational ocean state forecasts are also requested for planning effective utilisation of established wind turbines in their fields.

The ONGC's new project is an illustrative example of the type of benefits the OSF can confer on offshore oil and gas exploration industry. This project entails an investment of Rs 53,058 crore for drilling 45 wells in the east coast at 25 kilometres from the sea coast. The oil and gas production envisaged from the project during 2019-2031 is 26.71 million cubic metres per annum and 51.33 billion cubic metres per annum, respectively (Table II.4.5).

Table II.4.5: Estimated production and PV of annuity of crude oil and gas from ONGC's new project in Andhra Pradesh

ONGC - Crude Oil Production from the Project (2019-2031)			
		Amount/Value	Units
1	Annual oil production	26.71	Million cubic metre
		9.43	Million tonnes
2	International price of crude	54	USD (2015) per barrel
3	Barrel per metric ton	7.14	Per metric tonne
4	Exchange rate	64	USD (2015)
5	Annuity - International value of crude oil in domestic currency (1x2x3x4)	23,276	Rs. crore
6	PV of annuity for 13 years @12% social discount rate (one rupee)	6.42	
7	PV of annuity of crude oil output @ 12% for 13 years (5x6)	149,522	Rs. crore
ONGC - Gas Production from the Project (2018-2034)			
8	Annual gas production	51.33	Billion cubic metre
		1.82	Billion MMBTU
9	International price of gas per MMBTU	2.76	USD (2015) per MMBTU
10	Exchange rate	64	USD (2015)
11	Annuity - International price of gas in domestic currency (Rs.) (8*9*10)	32,084	Rs. crore
12	PV of annuity for 17 years @12% social discount rate (one rupee)	7.12	
13	PV value of annuity of gas output @ 12% for 17 years	228,438	Rs. crore

	Output Turnover		
14	Total PV of annuity - oil and gas	**377,960**	Rs. crore
15	Total investment	**53,058**	Rs. crore
16	Output turnover in terms of investment over the useful life @ 12% (14/15)	7.12	

	Benefit to Cost ratio		
17	**Total number of wells to be drilled**	45	
18	Number of wells to be drilled from 2018-2029	4	Per year
19	Number of wells to be drilled in 2030	1	Per year
20	**Expenditure on Exploration oil and gas**		
21	Expenditure per well for deep well drilling	140.0	Rupees crore per well
22	Annual expenditure for deep well drilling (2018-2029)	560.0	Rs. crore
23	PV of annuity for 12 years @12% social discount rate (one rupee)	6.2	
24	PV factor for the 13th year @12% social discount rate (one rupee)	0.2	
25	PV of expenditure (2018-2029) (22*23)	3,468.6	Rs. crore
26	PV factor for the 13th year @12% social discount rate for one well	32.1	Rs. crore
27	Total PV of expenditure for 13 years of drilling (2018-2030)	**3,501**	Rs. Crore
28	Value addition in oil and gas exploration (14 - 27)	**374,460**	Rs. Crore
29	Benefit to cost ratio at 12% social discount rate	**7.06**	

Source: Authors calculation

The total PV of annuity of crude oil and gas from the project is estimated at Rs 3.68 trillion. The strategic importance of this sector can be easily comprehended if the offshore crude oil production during 2013-14 was 18.20 million metric tonne (MMT) which is roughly twice the output of the proposed ONGC's new wells. The corresponding figure for natural gas production was 26.39 billion cubic metre (BCM) against the proposed 51.33 BCM from the new wells.

If OSF has a catalytic effect on the smooth expansion of offshore oil and gas exploration activities, its net economic benefits can be equated to the present value of value additions in crude oil and gas production. The estimated value addition is Rs. 3.74 trillion at 12% social discount rate.

IV. Ports and Harbours

ESSO-INCOIS has recently started a service that targets ports (minor as well as major), where it provides detailed information on the winds, waves, currents and tides for the coming two days at three-hourly intervals. The generalised forecasting system on the ESSO-INCOIS website, as well as the average first-day forecast, which is sent by mail, is also used by the port and harbour authorities for this purpose.

Based on our interview at the Krishnapatnam Port and other port authorities, OSF makes the port service operations safe by avoiding collision with other ship, loss of lives amongst other benefits. According to the port authorities, ESSO-INCOIS forecasts are highly accurate, reporting incidences of storms in the deep sea along with their intensity. The tsunami alert system along with the OSF forms a potent tool for traffic management for the ports. Further, discussion with the National Institute of Ocean Technology (NIOT), Vessel Management Cell indicated that on an average Eastern Coast region experiences 3 storms/cyclones per year while the Western Coast is reported to be much calmer with 1-2 storms/cyclones per year.

Since, ESSO-INCOIS predicts the intensity of the storms and regions affected very accurately, the port authorities are able to adopt measures for just in time evacuation resulting in atleast 3 days of productivity per year in the Eastern Coast and 1.5 days in the Western Coast. Since, the revenue realization per tonne of the cargo handle was Rs. 250 per tonne, the economic value of the increased productivity works out to be Rs. 669 crore over the useful life at 12% social discount rate. The detailed computations for major ports are shown in Table II.4.6 for east and west coast.

Table II.4.6: Estimated revenue loss for major ports in the East Coast and West Coast

East Coast			WestCoast		
Major Ports - Cargo handled	**FY 2013-14**	**Units**	**Major Ports - Cargo handled**	**FY 2013-14**	**Units**
Kolkata	41.4	million tonnes	Cochin	20.9	million tonnes
Paradip	68.0		New Mangalore	39.4	
Vishakapatnam	58.5		Mormugao	11.7	
Ennore	27.3		Mumbai	59.2	
Chennai	51.1		Jawahar Lal Nehru	62.4	
Tuticorin	28.6		Kandla	87.0	
Total East Coast	**275.0**		**Total West Coast**	**280.5**	

Productivity Loss due to Cyclone	3	days per annum
Cargo handled less	2.26	million tonne per annum
Revenue lost in cargo handling	56.5	Rs. crore
PV of annuity for 25 years @ 12% SDR (one rupee)	7.8	
PV of annuity of productivity gain due to OSF	443	Rs. crore

Productivity Loss due to Cyclone	1.5	days per annum
Cargo handled less	1.15	million tonne per annum
Revenue lost in cargo handling	28.8	Rs. crore
PV of annuity for 25 years @ 12% SDR (one rupee)	7.8	
PV of annuity of productivity gain due to OSF	226	Rs. crore

Source: Indian Port Association and authors calculations

Further, ESSO-INCOIS provides a specialised forecast service, the "Inland Vessel Limit", for the Maritime Boards of India. This service helps the Boards to limit smaller vessels, such as tugs, to the offshore limits based on the wave regime. ESSO-INCOIS has provided this service to the Maharashtra Maritime Board, A & N Port Board and Goa Maritime Board as a consultancy service and is currently providing this service operationally to the Gujarat Maritime Board.

NCAER visited the Gujarat Maritime Board (GMB) which has successfully linked all the minor port s in Gujarat with ESSO-INCOIS's OSF with an aim of improving their productivity. Discussions of the NCAER team with other port authorities indicated that non-major ports elsewhere does not avail the opportunity of utilizing the OSF. In order to estimate the additional potential economic benefits that OSF can generate if non-major ports are also linked, certain computations are shown in Table II.4.7 for the non-major ports.

In 2013-14, non-major ports handled 417.1 MT (43%) of cargo of the total 972.6 MT. The share of cargo handled in the non-major ports in the east and west was assumed to be in the same proportion as cargo handled in the major ports.

Table II.4.7: Estimated revenue loss for non-major ports in the East Coast and West Coast

East Coast		
Non-Major Parts - Cargo handled	**FY 2013-14**	**Units**
Traffic handled - East Coast Non-Major Ports	206.48	million tonne
Productivity Loss due to Cyclone	3	days per annum

WestCoast		
Major Ports - Cargo handled	**FY 2013-14**	**Units**
Traffic handled - west Coast Non-Major Ports	210.65	million tonne
Productivity Loss due to Cyclone	1.5	

Cargo handled less by	1.70	days
Revenue lost in cargo handling	42.4	Rs. crore
PV of annuity for 25 years @ 12% SDR (one rupee)	7.8	
PV of annuity of productivity gain due to OSF	333	Rs. crore

Cargo handled less by	0.87	days
Revenue lost in cargo handling	21.6	Rs. crore
PV of annuity for 25 years @ 12% SDR (one rupee)	7.8	
PV of annuity of productivity gain due to OSF	170	Rs. crore

The total economic value of the increased productivity works out to be Rs. 503 crore over the useful life at 12% social discount rate.

V. Shipping Community

ESSO-INCOIS provides generalised ocean state forecast information on winds, waves (wind wave and swell waves) and currents for the benefit of shipping communities. ESSO-INCOIS has also provided a very useful customised utility that is 'Forecast along ship track'. By using this facility, the captain of a vessel can take decisions about whether to continue along the same route He will have detailed information in the form of tables and figures on winds, waves (wind wave and swell waves) and the maximum wave likely to be encountered. The Shipping Corporation of India opines that safety and security of the vessels is of paramount importance and avoidance of collision and oil spill is an importance concern. These are intangible benefits which weights most on the shipping companies than fuel saving considerations.

VI. Fishing Communities

The fishing community is directly supported by ESSO-INCOIS and by several NGO partners of ESSO-INCOIS, such as Reliance Foundation, MS Swaminathan Research Foundation and NGOs that have a strong local presence. This support to the fishing community is very important given the socio-economic problems of the fishermen and ESSO-INCOIS has given high priority to reach out to them through diverse means. To the NGOs, ESSO-INCOIS provides the information on winds, waves and currents up to 100 km of the coastline, and the NGOs, in turn, disseminate these forecasts to a wide user community. The generalised forecasting system in the ESSO-INCOIS web as well as the average first-day forecast, which is sent by mail, is also used for this purpose. The benefits accruing from OSF for the fishing communities as an associated benefit of PFZ activities (in section II.3).

Conclusion: The overall economic benefits due to OSF service would be the cumulative benefits realised by Indian Navy, India coast guard, value addition of oil and gas exploration etc. per our computations exceed Rs 3.7 trillion. The gross investments made by ESSO-INCOIS to provide OSF in 2015 prices is Rs 6.47crore (including recurring capital of Rs 2.41 crore).

Chapter II.5 Economic Benefits of ESSO-INCOIS's Indian Tsunami Early Warning Centre (ITEWC)

Official sources attached to the Odisha government sought Rs 1,900 crore as a contingency fund for Phailin work related to relief and restoration. The state government also estimated that Rs 5,832 crore from the National Disaster Resource Fund (NDRF) would be required to meet the total expenses. Thus, a contingency plan as well as actual expenditure for relocation and rehabilitation can be a significant expenditure running to a few thousand crore. Although, this is related to cyclones and not Tsunami, it can be used to comprehend the magnitude of expenditure involved in relocation and rehabilitation of affected population. The economic benefits of the Tsunami Early Warning Centre can be simply accessed by the list of under-sea earthquakes in the Indian Ocean Region for which a 'No Tsunami Threat' advisory issued by ITEWC, ESSO-INCOIS avoids relocation and rehabilitation expenditures of human settlement in the affected regions . In this section we list the 23 cases from 2007 where 'No Tsunami Threat' was issued. Even if we assume an expenditure of around Rs 3,500 crore for one relocation and rehabilitation (based on the Phailin case study), the cumulative savings would amount to Rs 80,500 crore for period of 7 years (2007 through 2014); tantamount to an annuity of Rs 11,500 crore. The PV of annuity for 25 years at 12% social discount rate approximate Rs 90,000 crore.

The compounded investment in the Tsunami Early Warning Centre since its inception was a mere Rs 133 crore since in 2014 pricesat the social discount rate of 12 per cent. Obviously, the gross economic benefit far exceeds such gross investments.

Since its inception in October 2007, ESSO-INCOIS has monitored 436 earthquakes of magnitude greater than 6.5, of which 75 are in the Indian Ocean region. Year-wise details are given in Table II.5.1.

Table II.5.1: No. of earthquakes monitored since 2007

S. No	Period	No. of Earthquakes monitored at ITEWC (Magnitude>6.5)	Global Region	Indian Ocean Region
1	September 2007–March 2008	43	30	13
2	April 2008 – March 2009	61	42	19
3	April 2009 – March 2010	65	56	9
4	April 2010 – March 2011	72	63	9
5	April 2011 – March 2012	60	53	7
6	April 2012 – March 2013	57	48	9
7	April 2013 – March 2014	50	43	7
8	April 2014 – August 2015	28	26	2
Total		**436**	**361**	**75**

Advisories issued by ITEWC

Of the 436 earthquakes in the Indian Ocean region monitored by the ITEWC, only 37 were under-sea earthquakes with magnitude ≥ 6.5 that occurred in the Indian Ocean region. Only 7 earthquakesout of these 37 were tsunamigenic, for which the ITEWC analysed the model simulations, closely monitored the real-time water levels and issued earthquake/tsunami forecasts as per the Standard Operating Procedure (SOP). The forecasts issued by ITEWC for these tsunamigenic earthquakes are listed in Table II.5.2. ITEWC issued tsunami Warning/Alert/Watch only for select near-source areas in the Andaman & Nicobar Islands. For all these earthquakes, timely 'No Threat' bulletins were issued for India, thus avoiding false alarms and unnecessary evacuations. For 23 Indian Ocean earthquakes, a tsunami 'No Threat' bulletin was issued and those earthquakes are listed in Table II.5.3.

Table II.5.2: List of Tsunamigenic Earthquakes in the Indian Ocean Region for which ITEWC, ESSO-INCOIS issued Tsunami Warning/Watch/Alert Advisories

Date & Time (UTC)	Magnitude	Region Name	ITEWC Evaluation	Tsunami Observation
11-Apr-2012 10:43:10	8.2	Off west coast of Northern Sumatra	Tsunami Alert for Nicobar Islands and Watch for Andaman Islands and east coast of India	Generated a very minor tsunami that measured about 20 cm at Meulaboh, Indonesia
11-Apr-2012 08:38:36	8.5	Off west coast of Northern Sumatra	Tsunami warningfor Indira Point, Car Nicobar, Komatra&Katchal Islands of A & N Islands. Tsunami ALERT for rest of A & N Islands, Tamil Nadu, Andhra Pradesh. Tsunami Watch for few areas in mainland	A minor tsunami was generated that measured about 1 m at Meulaboh, 0.35 m at Sabang Indonesia and 0.30 m at Campbell Bay
10/01/2012 18:37:00	7.1	Off west coast of Northern Sumatra	Tsunami Watch for Nicobar Islands	No tsunami was generated
12-June-2010 19:26:47	7.5	Nicobar Island, India	No tsunami for Indian mainland. Tsunami Watch for Nicobar, Komatra&Katchal Island. Cancelled after 1 hour 30 mins.	A very minor tsunami was generated measuring 3 cm at Trincomalee

30-Mar-2010 16:54:50	6.9	A & N Islands, India	No tsunami for Indian mainland. Tsunami Watch for West & landfall islands, Flat islands, North Sentinel Islands, Port Blair. Cancelled after 1 hour 20 mins.	No tsunami was generated
12-Sept-2007 23:49:05	7.8	Kepulauan Mentawai Region, Indonesia	No tsunami alert for Indian mainland. Tsunami Watch for A & N Islands. Cancelled after 3 hours	
12-Sept-2007 11:10:26	8.5	Southern Sumatra, Indonesia	Tsunami Watch for A & N Islands, Orissa, Andhra Pradesh, Tamil Nadu, Kerala. Cancelled after 5 ½ hours	1 m high wave observed at Padang, Indonesia and 15 cm wave reported at Cocos Islands

Table II.5.3: List of under-sea earthquakes in the Indian Ocean Region for which a 'No Threat' advisory was issued by ITEWC, ESSO-INCOIS

Date & Time (UTC)	Magnitude	Region Name	ITEWC Evaluation	Tsunami Observation
14-Jun-14 11:11:05	6.5	South Indian Ocean	Tsunami threat does not exist for India	No tsunami was generated
21-May-14 16:21:51	6.6	Bay of Bengal	Tsunami threat does not exist for India	No tsunami was generated
21-Mar-14 13:41:09	6.5	Nicobar Islands	Tsunami threat does not exist for India	No tsunami was generated
01-Dec-2013 01:24:13	6.7	Banda Sea	Tsunami threat does not exist for India	No tsunami was generated
28-Sept-2013 11:29:00	6.8	Pakistan	Tsunami threat does not exist for India	No tsunami was generated
24-Sept-2013 11:29:00	7.6	Pakistan	Tsunami threat does not exist for India	A minor tsunami was generated that measured about 57 cm at Quarayat, 22 cm at Muscat and 20 cm at Suro, Oman
13-Jun-2013 16:47:00	6.8	South of Java	Tsunami threat does not exist for India	No tsunami was generated
10-Dec-2012 16:53:10	6.9	Banda Sea	Tsunami threat does not exist for India	No tsunami was generated

03-Sept-12 18:23:00	6.5	South of Java	Tsunami threat does not exist for India	No tsunami was generated
23-Jun-12 04:34:54	6.5	Northern Sumatra	Tsunami threat does not exist for India	No tsunami was generated
13-Oct-2011 03:16:32	7.0	South of Bali	Tsunami threat does not exist for India	No tsunami was generated
05-Sep-2011 17:55:33	6.6	Northern Sumatra, Indonesia	Tsunami threat does not exist for India	No tsunami was generated
03-Apr-2011 20:06:42	6.7	South of Java, Indonesia	Tsunami threat does not exist for India	No tsunami was generated
25-Oct-2010 14:42:20	7.5	Southern Sumatra, Indonesia	Tsunami threat does not exist for India	0.35 m wave was measured in Padang, Sumatra, Indonesia, and 0.4 m was measured in Rodrigues Islands, Mauritius
09-May-2010 11:29:44	7.4	Northern Sumatra, Indonesia	Tsunami threat does not exist for India	No tsunami was generated
06-Apr-2010 22:15:03	7.7	Northern Sumatra, Indonesia	Tsunami threat does not exist for India	40 cm surge was reported at Banyak Islands
30-Sep-2009 10:16:11	8.0	Southern Sumatra, Indonesia	Tsunami threat does not exist for India	28 cm wave was observed at Padang & 6 cm at Sibolga in Indonesia
02-Sep-2009 07:55:03	7.8	Java, Indonesia	Tsunami threat does not exist for India	A tsunami was generated, with maximum tsunami wave height of 40 cm near the coast of Java, Indonesia
16-Aug-2009 07:38:28	7.0	Southern Sumatra, Indonesia	Tsunami threat does not exist for India	A 19 cm wave was observed at Padang, Indonesia
10-Aug-2009 19:55:38	7.6	A & N Islands, India	No tsunami threat for India	No tsunami was generated
25-Feb-2008				
08:36:35	7.2	Kepulauan Mentawai Region, Indonesia	No tsunami threat for India	0.12m wave observed at Padang, Indonesia
20-Feb-2008 08:08:30	7.3	Coast of Northern Sumatra	No tsunami threat for India	No tsunami was generated
24-Oct-2007 21:02:49	7.1	Southern Sumatra, Indonesia	No tsunami threat for India	No tsunami was generated

The gross compounded investments (future value) since the inception of ESSO-INCOIS are traced department-wise in the table II.5.4.

Table II.5.4: Gross investment in ESSO-INCOIS, department-wise (in Rs crore)-FV of past investments and PV of likely economic benefits

Financial year	Potential Fishing Zone		Tsunami Storm Surge Warning Systems		Ocean State Forecast		Data Services		Computational Facilities		Human Capital
	Capital Cost	Recurring Capital Cost	Capital Cost	Recurring Capital Cost	Capital Cost	Recurring Capital Cost	Capital Cost	Recurring Capital Cost	Capital Cost	Recurring Capital Cost	
2002-03	0.05	0.01	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.07	0.33
2003-04	1.61	0.14	0.00	0.00	0.01	0.00	0.00	0.00	0.05	0.08	0.53
2004-05	0.08	0.01	0.00	0.00	0.01	0.00	0.00	0.00	0.10	0.12	0.72
2005-06	0.04	0.01	0.53	0.13	0.01	0.01	0.00	0.00	0.03	0.16	0.82
2006-07	0.01	0.00	22.95	7.46	0.01	0.01	0.00	0.00	0.01	0.23	1.21
2007-08	0.53	0.13	6.95	1.86	0.04	0.01	0.04	0.02	0.20	0.38	1.09
2008-09	1.61	0.15	0.35	1.59	1.11	0.31	0.17	0.02	1.69	0.85	2.25
2009-10	1.33	1.46	10.79	2.68	1.06	0.28	3.07	0.03	1.22	1.16	3.31
2010-11	1.02	1.02	1.50	2.46	0.00	0.31	1.70	0.06	0.28	1.81	4.41
2011-12	1.89	1.35	8.50	2.81	0.02	0.42	0.67	0.07	0.33	2.16	5.10
2012-13	1.62	1.17	0.45	1.79	0.23	0.35	0.28	0.09	3.07	2.45	5.49
FV 2014	17.09	7.79	96.64	36.48	4.06	2.41	8.77	0.39	10.38	13.81	39.53
Gross Economic Benefit (PV for 25 years)	For PFZ Advisories the total economic benefits amounts to Rs 23,800 crore.		80,500 infrastructure expenditure avoided in just 7-year period. The total economic benefits would amount to Rs 90,000 crore over the useful life at 12% social discount rate.		Economic benefits due to OSF amounts to Rs 3.7 trillion over the useful life at 12% social discount rate.		The future value of all past investments in ESSO-INCOIS amount to merely Rs 237 crore at 12 per cent discount rate compounded since 2002-03, which is a fraction of likely benefits. The economic benefits due to PFZ advisories amounts to Rs 23,800 crore.				

In view of significant economic benefits emanating from ESSO-NCMRWF –ESSO-INCOIS services, costing based on average cost for new services are envisaged; estimate for such standard cost are provided in the annex section. The Stress on average costs basis pricing is to encourage a wider application of services rather than the revenue maximisation from the potential users.

Chapter III Costing and Pricing of Products and Services of ESSO-NCMRWF & ESSO-INCOIS

Chapter III.1 Costing of services ESSO-NCMRWF

1. Introduction

Information on the costs of delivering specific government services is expected to play a more important role in the management of State finances. The NCAER has undertaken a study to measure the cost of providing weather- and ocean-related information services by two government agencies—ESSO-INCOIS and ESSO-NCMRWF. This section deals with measuring the cost of services provided by the ESSO-NCMRWF. In this study, the unit of measurement of cost of services is 'Rupees per hour' for all the services provided by ESSO-NCMRWF. The cost refers to the average of all the costs incurred by the Agency for providing varied services to different end-users. The Stress on average costs basis pricing is to encourage a wider application of services rather than the revenue maximisation from the potential users.

2. Services provided by ESSO-NCMRWF

The ESSO-NCMRWF is a national agency that generates real-time weather forecasts using advanced tools and techniques. The website of ESSO-NCMRWF states that it is a Centre of Excellence in weather and climate modelling under the Ministry of Earth Sciences. The mission of the Centre is to continuously develop advanced numerical weather prediction systems, with increased reliability and accuracy, over India and neighbouring regions through research, development and demonstration of novel applications while maintaining the highest level of scientific knowledge and technical skills. Its products include data relating to wind, geo-potential height, temperature, humidity, rainfall, dust forecasts, meteograms, rainfall probability, tropical cyclone strike probability forecast verification, etc. This makes its services quite comprehensive and critical to different types of economic activities in the economy.

While the worthiness of investment for establishing a country-wide network of AAS units is justified by the usage of the services provided by the agency, it is equally essential to record and understand how much of the resources have gone into the processes that resulted in providing data and maintaining the country-wide network. How much of the resources consumed can be identified with each of the services provided by the agency? If the services are to be made commercially available to specific users, how should such services be priced? These questions can be better addressed if the agency uses a structured cost system.

3. ESSO-NCMRWF Activities

(A) **Data Assimilation:** This major activity includes observational data reception, data quality control and data assimilation. Because the cost of data assimilation cannot be divided into the cost of different processes, data assimilation is taken to be the cost object for costing.

(B) **Modelling:** The second major activity is the modelling process. This process involves numerous sub-processes that lead to developing models that are used for providing the services. Here again, resources consumed in specific sub-processes are not recorded, and only the cost of the entire modelling is available. Hence, modelling is taken as the second cost object in the process of costing the services provided by the ESSO-NCMRWF.

(C) **Testing and Dissemination of Products:** In this process, the final products are made available to users. It is the third cost object identified for the purpose of total costing of the services.

4. Costing

The entire activities of the agency are integrated in the sense that they are linked in a value chain. The costing, therefore, is an aggregating process. The process of receiving observational data, quality control of the data and then assimilating them for evolving the final information services are linked sub-processes under the major process of 'Assimilation'. The Assimilation process is linked to Modelling Process, because the latter develops user-friendly products. This modelling process involves developing and testing new models, while at the same time providing tested models for weather prediction by ingesting the assimilated data. The modelling process largely consumes valuable human resources in the form of scientists. Their contribution is very valuable but difficult to measure for costing purposes. Hence, their salaries are taken as the cost. Finally, product dissemination to end-users involves a process and the resources consumed in despatching the product-services are the cost of the dissemination process. First, the costing of each of the three processes are presented separately. Then, the three tables are consolidated.

4. A: Data assimilation costs

The costing of the Data Assimilation process is presented in Table III.1.1. Cost information was provided by the ESSO-NCMRWF except that the salary information is drawn from Government of India pay scales for scientists and other staff. Major capital expenditures are included in the assimilation cost sheet. Equipment cost, included under HPC resources, is amortised for a period

of 15 years, assuming the average life span to be 15 years. Annual contributions to WMO and NCEP/UKMO have been fully charged to the assimilation process.

Table III.1.1: Costing Assimilation of Data

S. No.	Cost head	Cost (Rs)	Source of information	Remarks
1.	HPC resources	151,966,667	Data from ESSO-NCMRWF	Includes amortised cost(see Table III.1.2)
2.	Salaries	19,680,000	.....	Salaries as per ESSO-INCOIS sheet*
3,	Proportionate Computer network cost	1,664,000	.....	Salaries, cost of computer network divided between three functions
4.	Proportionate Administrative salaries	1,652,000	Data from ESSO-NCMRWF	Total admin. cost given in Table III.1.3 divided between three cost objects
5.	ProportionateOverheads (Other exp.)	67,166,667	Data from ESSO-NCMRWF	Total other exp, given in Table III.1.4 divided between three cost objects
6.	ProportionateKnowledge upgrading expenses	833,333	Data from ESSO-NCMRWF	Knowledge cost of Rs.25 lakh distributed between three cost objects
7.	Contribution to WMO	10,000,000	Data from ESSO-NCMRWF	
8.	Contribution to Monsoon desk NCEP/UKMO	15,000,000	Data from ESSO-NCMRWF	
	Total	1,627,962,667		

Columns 1, 4 and 5 are taken from Tables III.1.2, III.1.3 and III.1.4, respectively, which are presented below.

Table III.1.2: HPC resources

Equipment	Cost (Rs.)	Amortised value per annum (Rs.)*	Annual maintenance (Rs.)	Total (Rs.)	Remarks
CRAY-SV1	95,000,000	6,333,334	14,700,000	21,033,334	*Amortised for 15 years
CRAY-XIE	200,000,000	13,333,334	17,600,000	30,933,334	*Amortised for 15 years
IBM-P6	470,000,000	31,333,334	18,000,000	4,933,334	*Amortised for 15 years
IBMiDataPlex	760,000,000	50,666,667		50,666,667	
Total		101,666,669	50,300,000	151,966,667	

Table III.1.3: Administrative staff salary

No. of positions	Monthly salary (Rs.)*
Deputy Secretary = 1	80,000
Under-Secretary	75,000
Section office = 1	55,000
Assistant = 2	100,000
Lower division clerk = 2	58,000
Maintenance staff = 3	45,000
Monthly total	413,000
Annual salary	4,956,000
Prop. Distribution to three depts.	1,652,000

**Salary amounts have been drawn from central government employees' pay scales.*

Table III.1.4: Other annual expenditures

Heads of expenditure	Amount (Rs.)*
Non-Plan	50,100,000
Plan revenue	105,400,000
Plan capital	23,000,000
Total	201,500,000
Prop. Distribution to each of three cost objects	67,166,667

*Note: *Expenditure amounts as given in the sheet from ESSO-NCMRWF*

4. B: Modelling cost

This section of the ESSO-NCMRWF is the hub of its technical capability. The value of the services provided by the agency is largely driven by these activities. The valuation of intellectual capabilities is yet to be an acceptable norm under Cost Accounting. Until then, we cost the modelling functions of the organisation only in terms of money spent. The cost of the modelling function is given in Table III.1.5 below.

TableIII.1.5: Cost of Modelling

Cost head	Annual amount (Rs.)	Remarks
Salaries	27,564,000	For scientists and other technical staff at government pay scales
Prop. Computer network expenses	1,664,000	Includes only salaries of scientists and other technical staff engaged in computer network activities equally distributed between three functions
Prop. Administrative Expenses	1,652,000	Includes only salaries of staff engaged in administrative activities
Prop. Other annual Expenditures	67,166,667	Details as given in Table III.1.4 above
Prop. Knowledge upgradation expenses	833,333	Knowledge cost of Rs.25 lakh distributed between three functions
Total	98,880,000	

4. C: Cost of Product Dissemination

The ESSO-NCMRWF provides several products to users. The final dissemination of products involves distinct activities that are performed by designated persons. Their salaries constitute the main cost element of this function. The salary figures are taken from Government of India pay scales. The resources spent in using the computer network are allocated to this function on a proportionate basis. The function is also charged with a proportion of administrative staff salaries and annual expenditures as shown in Tables III.1.3 and III.1.4 above. The function is also charged for training and knowledge upgrades to its personnel. All these are shown in Table III.1.6 below.

Table III.1.6:Cost of Product Dissemination

Cost Head	Annual Cost (Rs.)	Remarks
Salaries	7,644,000	Salaries of scientists & technical staff
Prop. Computer network cost	1,664,000	Includes only salaries of scientists and other technical staff engaged in computer network activities equally distributed between three functions
Prop. Administrative expenses	1,652,000	See Table III.1.3
Prop. of other annual expenditures	67,166,667	See Table III.1.4
Prop. Knowledge upgradation expenses	833,333	Knowledge cost of Rs.25 lakh distributed between three functions
Total	78,960,000	

5. Consolidation of three functions:

Tables III.1.4, III.1.5 and III.1.6 presented above show the costs of each of the three major functions in the value chain of the ESSO-NCMRWF. Each function plays a distinct and significant role in the working of the ESSO-NCMRWF. Each one creates value and passes the output to the next process until it reaches users. So, to arrive at the cost of the products given out by the agency, we need to consolidate the costs of all three functions. The value chain is given below:

Therefore, the cost follows the value chain. The total cost of Data Assimilation function will be added to the cost of the Modelling function, and the total cost of the Modelling function will be added to the Distribution function. This way, all the costs are aggregated to the last function in the Value Chain, after showing the cost of each individual function. The cost aggregation is given in Table III.1.7:

TableIII.1.7:Consolidation of costs

Costs	Assimilation	Modelling	Distribution	Remarks
Functional cost	Rs. 1,627,962,667	Rs. 98,880,000	Rs. 78,960,000	See Tables III.1.1, III.1.5 and III.1.6
First transfer		Rs. 1,627,962,667		
First Sub-Total		Rs. 1,726,842,667		
Second Transfer			Rs. 1,726,842,667	
Total Cost			Rs. 1,805,802,667	

The operation of the ESSO-NCMRWF is broadly divided into (i) four DA cycles per day, each DA cycle taking 1 hour and 30 minutes, and, (ii) Ten day forecast taking 2 hours. Normal working time of 8 hours for 365 days has been taken as the basis. We present below the cost per hour of the operations, cost per day of operations, cost per DA cycle and cost of 10 day- forecast:

TableIII.1.8:Cost by operations of ESSO-NCMRWF

(1)	Total annual cost of all the services (Table III.1.7)	Rs.1,805,802,667
(2)	Total working hours in a year=365X8hrs	2920 hours
(3)	Total cost per hour (1)%(2)	Rs. 618,426
(4)	Total cost per day(3) x 8hours	Rs. 4,947,408
(5)	Total cost per DA cycle	
	for 1 hour for half hour Total	Rs. 618,426 Rs. 309,213 Rs. 927,639
(6)	Total cost for 4 DA cycle in a day (5) x 4	Rs. 3,710,556
(7)	Total cost 10-hour forecast (3) x 2	Rs. 1,236,852

6. Conclusions

The above paragraphs show the cost of all the services provided by the ESSO-NCMRWF to its users. The calculated cost per hour shows the cost per hour working of the organisation. The time taken for providing a specific product to a distinct user will be applied to the cost per hour

computed to arrive at the cost of the service provided to that customer. The functional cost has been computed, however,from the accounting data made available for the study. The figures may be updated to arrive at a cost based on current data. Alternatively, the cost arrived at in Table III.1.7 can be increased by about 20% to include the normal increase in the cost of equipment, maintenance and human resources.

We suggest the following steps to bring the costing system into use as a part of the ESSO-NCMRWF's routine administrative exercise.

1. Incorporate a costing system that conforms to cost accounting standards, as part of the accounting process. Software is available for incorporating a costing system along with the accounting process under ERP.
2. Since the services provided are various, incorporate a system of recording the time spent for executing each service, which can be further split into customer-specific time spent. This step would help significantly in various decisions relating to pricing the services provided. We suggest introducing Activity-Based Costing so that costs of output services can be measured accurately, along with information available on the cost of each specific activity or group of homogeneous activities.

Chapter III. 2 Costing of services of ESSO-INCOIS

1. Introduction

Information on the costs of delivering specific government services is expected to play a more important role in the management of State finances. In an environment of upward pressure on expenses and constraints on revenues, agency managers must focus on achieving value for money in the delivery of government services. These pressures are similar to those faced by private sector managers who look at the finance function to provide more comprehensive information to support decision-making and overall cost management. A study has been undertaken by the NCAER to measure the cost of providing weather- and ocean-related information services by two government agencies—ESSO-INCOIS and ESSO-NCMRWF. This section deals with measuring the cost of the services provided by each of these two agencies.

Weather/Ocean forecasts represent a classic case of a 'public good'. As such, there is a compelling economic argument for government funding to develop and deliver forecasts. This principle is accepted around the world where governments continue this form of investment. The question is the priority and level of funding to be provided. The present section outlines the mechanism for measuring the explicit costs incurred in providing the services to evaluate the value for money in terms of the considerable and diverse benefits to communities and industries.

Service costing involves providing information to managers about the cost of the services produced by their agency. This service costing information depends on the management decision to be made about the intensity of services provided and the specificity of the end-users' needs. This report provides a model for costing outputs in a variety of situations, including rate development for cost recovery and costing results within the operational plans. To this end, definitions of basic cost accounting terms and concepts are provided. In addition, the steps that are typically followed in the costing of outputs are discussed, together with the decisions that must be made at each step and the cost components and calculations required to support each decision.

Costing of services is the process of providing cost information to managers of the agency providing services. The nature of the information provided depends on or driven by the decisions taken by the managers.

2. ESSO-INCOIS Services

ESSO-INCOIS provides information that can be used to understand the ocean and climate better, and can significantly improve planning and management of critical sectors of the economy, such as the fisheries, energy and resource sectors. These improved forecasts are expected to significantly assist decision-makers in industry and government, especially in activities that are directly impacted by weather and climate conditions.

Cost considerations and easy access contribute to the wide use of free weather/ocean information sources. However, these sources may have problems with timeliness and a lack of detail that may result in the use of inaccurate weather/ocean information. The accuracy of weather sources is the main barrier preventing the wider use of weather information. One key component of helping to meet these challenges is obtaining and using accurate weather/ocean information. The benefits of accurate weather/ocean information are clearly evident when contrasted with some of the costs of inaccurate weather/ocean information, such as excessive use of materials, failure to respond in a timely matter to a storm event (resulting in greater crash risk and user delay) and unplanned use of overtime staffing. Improvements in weather/ocean information can help in all stages of winter storm response, including pre-, during and post-storm.

Inaccurate weather/ocean information to end-users may result in incurrence of unwarranted expenditures like evacuating the people living in 'cyclone/tsunami' prone areas. Hence there is a need to ensure dissemination of accurate weather/ocean information. Steps taken to ensure accuracy of information may involve additional cost in generating the required accurate information, but it is worth the expenditure.

The spectrum of activities of ESSO-INCOISincludes:

1. Potential Fishing Zone (mission mode)
2. Experimental Ocean State Forecast (mission mode)
3. Marine Metrological Advisory Services
4. Web-based Ocean Information Services
5. Value-added Services and Decision Support Systems

Functional Groups: ESSO-INCOIS is engaged in various activities that help it to provide the above-mentioned services to end-users such as fishermen, shipping companies, government agencies

and academic bodies. These activities are performed by various groups working within the organisation structure of ESSO-INCOIS.

The groups are:

1. Modelling and Ocean Observation Group (MOG)
2. Data Management Group (DMG)
3. Advisory Services and Satellite Oceanography Group (ASG)

3A. Potential fisheries zone group (PFZ)

3B. Tsunami Warning group (TSW)

4. Information Services and Ocean Sciences Group
5. Computational Facilities and Web-based services group
6. Executive Services Group: Administration & Establishment (ESG)

Each group is engaged in unique work that involves either final output-data or intermediary output-data. Groups 5 & 6 are engaged in supporting Groups 1-4. The groups act as channels through which the final services get formulated for transmitting them to users. Based on discussions with ESSO-INCOIS representatives and the reported financial statements of the organisation, we concluded that these groups are the cost centres through which the cost for the services provided are incurred. The objective of the present study is to identify the cost incurred by the ESSO-INCOIS in providing different final output-data services.

3. Costing System:

This section explains the basic concepts of cost accounting. The sections that follow demonstrate how the basic concepts can be applied in any general government sector agency.

Costs refer to resources expended to achieve a particular result, such as a service, a product or an asset, and can include expenditures from more than one fiscal year. The cost incurred by a government agency include expenditures made towards employees of the agency, operations of the activities of the agency, maintenance of its assets and estimated value of depreciation on assets.

Cost accounting refers to the processes whereby cost of resources consumed are attributed to results. A **cost object** is an item whose cost needs to be computed.

Organisations set up costing systems to provide this information. These systems accumulate the costs that can be attributed to the cost object.

Traditionally, cost objects are classified as follows:

- Functional departments, independent branches/business units.
- Final products or services
- A distinct project

Modern costing systems extend this range to include cost objects such as:

- Activities. An activity is a 'thing that gets done', as part of the process of providing the final output/services, such as the process of modelling.
- Suppliers and customers. In the case of general government sector agencies, it is the cost of servicing particular groups of clients.

In the specific case of ESSO-INCOIS, the cost objects could be each of the services provided by the organisation, the six groups through which the operations of the agency are performed, or any specific activity for which the agency wants to compute the cost.

3. A. Cost Drivers:

A cost driver is a factor that causes costs to be incurred. For example, the level of activity or volume of services rendered will affect the total cost of the cost object. In a client service department, a factor could be client requests for information; in this case, the cost driver would be the number of client requests, or the nature of client requests that measured in terms of hours required to be spent by the agency in generating the information

The cost drivers may differ between activities or group of activities. It may also change from one period to another depending on changes taking place in the nature of client-requests. An activity may be driven by several underlying cost drivers but the most proximate is to be identified.

In weather-related services, the time factor could be an important cost driver. In the present study, time measured in hours is taken as the cost driver. This is the time taken either to provide a particular service or provide information to another agency.

3. B. Direct and indirect costs:

A direct cost can be directly traced to a cost object in an economically feasible (i.e., cost beneficial) manner. For example, the salary (cost) of a scientist who works entirely on the production of one service is a direct cost of producing that service (cost object). The cost of employees working on more than one service can be traced to these services using a time allocation system.

An indirect cost cannot be directly traced to a cost object in an economically feasible manner. It is allocated to the product on a cost allocation basis. This cost allocation basis should reflect how the underlying resources are consumed.

For example, organisation support functions such as administrative assistance, IT and finance are essential to produce services. However, it may not be possible or economically feasible to trace such costs to individual services. The costs of support activities in an agency may be allocated to the operational divisions on some rational basis. In the present exercise, the cost of the Executive Services Group (ESG) in ESSO-INCOIS is distributed equally among all other groups under the assumption that ESG supports all other groups equally.

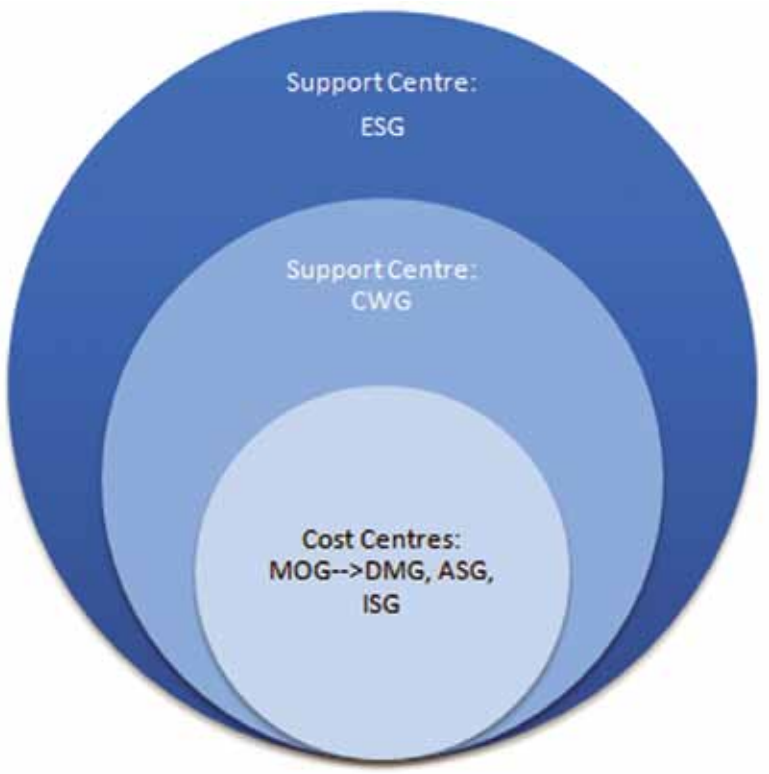
The relationship between cost drivers and costs is cost behaviour. The analysis of cost behaviour can be complex, but it is very important when measuring the impact of change. For example, it is needed to calculate forward estimates that reflect expected changes in demand for future services.

Fully distributed costs are used when we need to know the 'true' or full costs incurred by an agency.

Avoidable costs are costs that would be avoided if a good or service is not produced. Avoidable costs are typically used to make decisions about future courses of action, such as deciding whether to spend resources on a particular activity.

4. Costing Process for ESSO-INCOIS

The service costing approach described below is very simple. It involves using information on costs at the agency level and in functional areas to calculate the costs of services and service groups such as MOG and DMG. The service groups are the cost centres that perform the activities of ESSO-INCOIS and provide services to end-users. The ESG provides administrative support to all other groups and the Computer Facilities Group provides IT systems and support to all other groups.



Each service group handles specialised activities. The MOG handles data observation using various equipment and also conducts research studies. It provides the DMG group with data inputs. The DMG manages the data received; it provides data to other service-providing groups in ESSO-INCOIS, processes the data to suit the specific needs of end-users and acts as the repository of archived data. The ASG has two divisions—PFZ and TSW— that handle specialised activities in fisheries-related information and tsunami warnings. The ISG provides similar specialised services in ocean-related information. Each group has a structured organisation with dedicated personnel. Although a significant portion of their activities are automated through IT systems that operate 24 hours a day, the decision-making process by individuals is usually done during working hours, which is about 8 hours a day. The present study has taken each group that was identified as a cost centre and calculated the average cost of hourly operation for each cost centre. While calculating the costs, the linkages between the groups has been taken into consideration, which is illustrated below:

ESG ⟹ CWG; MOG; DMG; ASG-PFZ & TSW; ISG

CWG ⟹ MOG; DMG; ASG-PFZ & TSW; ISG

MOG ⟹ DMG

4. A. Services provided by ESSO-INCOIS

The services provided by ESSO-INCOIS are:

1. Ocean state forecast service for Maldives
2. Tsunami services:
   (i) Tsunami early warnings
   (ii) Communication tests
3. Ocean state forecasts & high wave alerts
4. Potential fishing zone advisories; tuna fish advisories
5. Global ocean analysis products
6. Geospatial services
   (i) Coastal vulnerability index
   (ii) Coral bleaching alerts
7. Data services
   (i) in situ & remote sensing data
   (ii) data distribution

The list of services above is based on the contents of the Annual Reports of ESSO-INCOIS.

4. B. Source of cost data

Information on costs for the study has been collected from the Annual Report of ESSO-INCOIS for the year 2012-13 and the information provided by the heads of different groups. There seems to be no structured system in place at ESSO-INCOIS for computing the cost of its activities. The financial statements that form part of the Annual Report are based on the government's reporting requirements and are therefore for ESSO-INCOIS as a whole.

We were informed during the study that the rate of costs for services provided is in force for specific purposes and those rates were determined more than 10 years ago. We could not discern the basis for computing those rates and hence we are unable to comment on the appropriateness of those computations.

The following paragraphs present the process followed in computing the cost per hour of operation for each group except for the ESG and CWG, which are support cost centres and their costs were distributed among other groups.

4. C. Costing of the Executive Services Group (ESG)

In the process of computing the cost of final services provided by ESSO-INCOIS this is the first step.

ESG is dedicated to providing administrative, finance, procurement and estate maintenance services to other groups. It supports, facilitates and promotes the vision and mission of the organisation. It also provides the organisational structure and technology to ensure sound and efficient delivery of training allowing the scientists to focus on achievement and programme requirements. The ESG ensures adherence to policies, preserves integrity, safeguards the security of all records and provides effective service to constituents.

This group provides services to other groups in ESSO-INCOIS, except the CWG, which is another support cost centre that also provides services to ESG. We have, however, not considered the inflow of services from the CWG to the ESG while measuring the total cost of ESG.

TableIII.2.1: Cost sheet for ESG

Cost item	**Cost per year (Rs.)**	**Source of cost information**	**Remarks**
Annual operational cost	35,344,838	ESSO-INCOIS expenditure outlay for Financial Year 2012-13 (A/c. Dept.)	Cost includes operational and maintenance expenditure, establishment expenses and administrative. expenses
Overheads	34,385,000	Annual Report 2012-13	Depreciation for the building and fixed assets as given in Annual Report.
Salaries	14,767,824	Salary sheet (A/c. Dept.)	Salaries included are for one month in 2014-15
Annual cost	8,447,662		The total cost of ESG is distributed among other groups on an equal basis.

We have not computed the hourly cost of the ESG because it provides support to the entire organisation. For any decisions such as the expansion of the ESG, the total cost of the group is sufficient to measure the financial impact of the decision. The total cost of the ESG is distributed among all other groups since those groups are the beneficiaries of the services internally provided by ESG.

4. D. Computer and Web Facilities Group (CWG)

The computer facilities group is also a service provider group. It provides computing facilities to all other groups in ESSO-INCOIS, including the ESG. However, since our focus is to compute

the total cost of final services provided to external users, we have not considered the services provided by the CWG to the ESG

The CWG plans, implements and maintains the hardware and software at ESSO-INCOIS and its activities can be described as computing and web-based services. Accordingly, the annual operational cost includes the depreciation of computers and related peripherals, and annual maintenance.

TableIII.2.2: Cost Sheet for CWG

	Cost Heads	**Cost per Annum (Rs.)**	**Source of Information**	**Remarks**
1	Annual Operating Cost	48,729,300	Annual Report 2012-13 & Data Sheet from HOD	Cost includes depreciation on computer and peripherals plus annual maintenance cost contract (signed for 3 yrs.) by ESSO-INCOIS for all IT systems
2	Overheads	------		
3	Salaries	8,951,820		Payroll (A/c.Dept.)
4	Annual Cost = (1+2+3)	57,681,120		
5	Share of ESG Cost	16,899,532		
6	Total Annual Cost = 4+5	**Rs. 74,580,652**		**Total cost to be distributed among MOG, DMG, ASG & ISG**

4. E. Modelling and Ocean Observation Group (MOG)

The Modelling and Ocean Observation Group (MOG) provides the technical base for data observation and develops suitable models. The group is also engaged in expanding the knowledge base in the area of weather information through research and publications. In the process of providing ocean-related information to end-users, MOG provides data to the Data Management Group. So, after independently computing the cost of MOG, the cost is transferred to the DMG since the latter processes data that is collected through the activities of MOG. The cost structure for MOG measures the cost incurred by MOG for all its activities.

TableIII.2.3: Cost sheet for MOG

S. No.	Cost heads	Cost per year (Rs Lakhs)	Cost per hour (2,340 hrs. a year)* Rs Lakhs	Source of Information	Remarks
I	Annual equipment cost	1,355.00	Rs 0.58		
II	Overheads	902.29		Annual Report 2012-13	
III	Salaries	164.08		Payroll	
IV = I+II+III	Annual operational cost	2,421.38	Rs 1.03		
V.	Share of ESG cost	168.99		Table III.2.1	
VI.	Share of CWG cost	186.45		Table III.2.2	
VII = IV+V+VI	Total annual cost	2,776.82	Rs 1.19		Cost transferred to DMG

*Note: *9 hrs. for 5 days a week for 52 weeks = 2,340 hrs.*

MOG deploys different types of equipment that observe weather/climatic conditions and transmit the observations to ESSO-INCOIS. Though data transmission is managed by the DMG, MOG is also engaged in enriching the knowledge base of ESSO-INCOIS. The research activities of MOG are expressed in terms of research papers that are published by ESSO-INCOIS as well as leading international journals. We could not find any suitable tools to measure the intellectual output (value-added service) of MOG, but the economic benefits of this service would be significant enough to justify the cost incurred. Table III.2.4 shows the hourly cost incurred in operating the equipment deployed by MOG. If we add the cost incurred on human resources (salaries) and a share of the overhead cost, we arrive at the annual operating cost. Since no final data output is given by MOG, the entire cost is transferred to the DMG which, in turn, manages the data for ESSO-INCOIS.

TableIII.2.4 Equipment Cost Sheet for MOG

S. No.	Equipment	Cost (Rs. Lakh)	Amortized value for year (Rs. Lakhs per year)	Source of data	Remarks
I	26 Buoys-USA		15	HO MOG	
II	7 Moorings	700	140	HO MOG	5 yrs. Amortized
IV	30 Drifters		300	HO MOG	
V	3 Xbts		300	HO MOG	
VI	118 Agro floats		600	HO MOG	
VII	Equipment cost per year for MOG		1,355	Rs. 0.58 lakhs	Per hour equipment cost

4. F. Data Management Group (DMG)

As the central repository for marine data in the country, ESSO-INCOIS receives voluminous oceanographic data in real time from a variety of *in situ* and remote sensing systems. The Ocean Information Bank provides information on physical, chemical, biological and geological parameters of oceans and coasts on spatial and temporal domains that is vital for both research and operational oceanography. It is supported by data received from Ocean Observing Systems in the Indian Ocean (both in situ platforms and satellites) as well as by a chain of Marine Data Centres.

Further, ESSO-INCOIS has been designated the National Oceanographic Data Centre by the International Oceanographic Data Exchange Programme (IODE) of the International Oceanographic Commission (IOC). It also serves as the National Argo Data Centre, the Regional Argo Data Centre, the regional data centre and the clearing house for the Indian Ocean region for the IOGOOS Programme.

The DMG enables ESSO-INCOIS to achieve these targets. Its activities include receiving, processing with quality control and disseminating data to users both inside and outside ESSO-INCOIS. It also stores all the data owned by ESSO-INCOIS for future use. Along with its data managing activities, the group provides the value-added services of guiding research. (The DMG allows Research students from Academic institutions to study and conduct research from the data provided by the Group. Scientists working in this group spend portion of their working time in guiding the students.) The real-time data system is managed through automated mechanisms round the clock. Data is processed to create delayed-time data for use by other groups within ESSO-INCOIS as well as by outsiders. Data is also processed for consultancy projects undertaken by ESSO-INCOIS. The DMG is also responsible for providing data online through the ESSO-INCOIS website. The cost structure for DMG activities is given below in Table III.2.5 and III.2.6

TableIII.2.5: Cost sheet for DMG

Col.no.	**Cost heads**	**Cost per year (Rs.)**	**Cost per hour (2,340 hrs. a year)***	**Remarks**
I	Data cost	382,082,583	Rs.163,283.16	Data cost is the total cost of MOG
II	Salaries	9,357,984		Source: Payroll
III	Overheads	20,136,368 #		Source: Annual Report 2012-13
IV=I+II+III	Annual operational cost	411,576,935	Rs.175,887.58	

*Note: *9 hrs. for 5 days in a week for 52 weeks= 2,340 hrs.*

Table III.2.6: Overhead costs for DMG

Cost heads	Cost per year (Rs.)	Remarks
Revenue expenditure	8,126,139	Source: Annual Report 2012-13
Operation & maintenance	10,698,432	Source: Annual Report 2012-13
Establishment expenses	935,896	Source: Annual Report 2012-13
Administration expenses	375,901	Source: Annual Report 2012-13
Total overheads cost	**20,136,368**	

The total operational cost of DMG at Rs.175, 888 per hour is a composite cost that includes real-time data cost for receiving data and delayed-time data cost for processing the data. Since users have different needs, we note that costing the customised data services provided to them, especially those outside ESSO-INCOIS, would significantly help in decisions such as pricing. Such a costing to measure user cost is possible only when the hours spent in processing each customised dataset is measured and recorded, so that the total cost can be distributed on an hourly basis among all users.

4. G. Information Services and Ocean Sciences Group (ISG)

The ISG is engaged in numerous activities such as operational ocean forecasting, (informed by ESSO-INCOIS that it is sort of technical consulting but not training) setting up real-time observational systems for 7days week @ 10 hrs., operational modelling tools for forecasting for 7 days @ 10 hrs., incident-based bio-geochemistry and water quality forecasting, value added/ consultancy services, training and capacity building, numerical wave modelling, utilisation of buoy as well as satellite data, and supporting daily operational wave forecasting, consultancy project work and study of wind-generated ocean wave models, ecosystem modelling, coastal ocean wave modelling, buoy data analysis, maintenance and installation of ocean observation network, analysis of argo-oxygen/ bio-argo data and operationalising oil spill trajectory predictions. It operates 10 hours a day for 7 days in a week. The costs identified for the group are towards all these activities, because the time spent on each of the activities is not recorded. The costs incurred are towards installing and maintenance of data observing equipments, processing the data and providing data to users. The costs identified with the ISG are given in Table III.2.7 and III.2.8:

Table III.2.7: Cost sheet for ISG

Col.no.	Cost heads	Cost per year (Rs Lakhs)	Cost per hour (7x10x52=3640 hrs.)* Rs Lakhs	Remarks
I	Annual equipment cost	417.00	Rs 0.04	Source: HOD-ISG
II	Overheads	361.00		Source: Annual Report
III	Salaries	151.59		Payroll
IV=I+II+III	Annual operating cost	929.72	Rs 0.26	

*Note: *Working time per day has been taken as 10 hrs. for 7 days a week as informed by HOD-ISG.*

TableIII.2.8: Equipment cost for ISG

Equipment	Total cost (Rs. Lakhs)	Cost per year (Rs.lakhs)	Source	Remarks
16waive rider buoy	1360	272	HOD-ISG	5 yrs. Amortized
1 waive height meter	50	10	HOD-ISG	5 yrs. Amortized
20 AWS	600	120	HOD-ISG	5 yrs. Amortized
Data purchase cost		15	HOD-ISG	
	Total	417		

4. H. Advisory Services and Satellite Oceanography Group (ASG)

The ASG group along with the ISG and DMG provides data services to users outside ESSO-INCOIS. Its activities are linked to Potential Fishing Zone (PFZ) Advisories, Ocean Colour Applications, Coastal Geospatial Applications, Tsunami Early Warning Systems, Satellite Communications Infrastructure Development & Maintenance, the Indian Seismic & GNSS Network (ISGN) Project and the Secretariat of the GOOS Regional Alliance in the Indian Ocean (IOGOOS). It is engaged in value-added services also. However, for the purpose of costing, we considered two groups: (i) Tsunami Warning Centre, which monitors tsunamis and (ii) Potential Fishing Zone, which handles information relating to fisheries zone, coral bleaching, consultancies and research. The cost elements that are clearly identified with either the TSW or the PFZ are structured as incurred. Other costs, such as the total salary bill of the ASG, are equally apportioned between the PFZ and the TSW. The working hours for the TSW is derived as 24 hrs. x 365 days, and for the PFZ centre it is 15 hrs. x 365 days, as given by the respective department heads. The cost sheet for the two centres are given in Table III.2.9, III.2.10 and III.2.11:

Col.no.	Cost heads)	Cost per year (Rs.)	Cost per hour (8,760 hours)*	Source of information	Remarks
I	Annual equipment cost	79,097,024	Rs.9,029.34	HOD-TSW	
II	Overheads	154,212,529		Annual Report 2012-13	
III	Salaries	13,123,458		Payroll	
IV=I+II+III	Annual operating cost	246,433,011	Rs.30,160.43		

TableIII.2.10: Equipment cost of TSW

Col. no.	Cost head	Cost (in Rs Lakhs)	Source of information	Remarks
1.	Seismic Data Stn.-17	5.47	Cost sheet from TSW	Cost is the 5 years amortized value
2.	Tsunami Buoys-2	126.31	Cost sheet from TSW	Cost is the 5 years amortized value
3.	Tide Gauge Stations-21	4.64	Cost sheet from TSW	Cost is the 5 years amortized value
4.	Software (ArcGIS+MATLAB)	6.89	Cost sheet from TSW	Cost is the 5 years amortized value
5.	Top. Data(ALTM)	340.00	Cost sheet from TSW	Cost is the 5 years amortized value
6.	R&D Cost	113.03	Cost sheet from TSW	
7.	Maintenance Cost	193.58	Cost sheet from TSW	
8.	Dissemination Cost	1.02	Cost sheet from TSW	
9.	Total	790.97		

TableIII.2.11: Costsheet for Potential Fishing Zones (ASG)

S. No.	Cost Heads	Cost Per year (Rs lakhs)	Cost per hour (Rs lakhs) (3650 hours)*	Source of Information	Remarks
I	Annual Operations Cost	363.90	RS. 0.10	Cost Sheet PFZ	
II	Overheads	570.51		Annual Report 2012-13	
III	Salaries	131.23		Payroll	
IV=I+II+III	Annual Cost	1,065.66	RS.0.29		
V	Prop. Cost of ESG & CWG	177.72	RS.0.04		
VI (IV+V)	Total PFZ Cost	1,243.38	RS.0.34		

*Note: *5475 hours per year calculated at 15 hrs. for 365 days.*

TableIII.2.12: Equipment cost for PFZ

Col.no.	Cost head	Cost per year	Source of information	Remarks
1	Software Cost (3 ArcGIS+4 ERDAS+1 ENVI)	1,590,000	Cost Sheet-PFZ	Cost is 5 yrs. amortised value.
2	Display Boards-100+FAX	10,467,960	Cost Sheet-PFZ	Cost is 5 yrs. amortised value.
3	Dissemination Cost	943,680	Cost Sheet-PFZ	
4	R&D Cost	17,000,000	Cost Sheet-PFZ	XII Plan period cost
	Total	30,001,640		

4. I. Consolidated cost sheet of ESSO-INCOIS

From Table III.2.1 to Table III.2.12, we have presented the cost of individual functional groups of ESSO-INCOIS. As observed earlier, ESG, CWG and MOG do not provide final products to external end-users. Hence, the cost of these functions should be apportioned among the other three groups: DMG, ISG and ASG (PFZ + TSW). This has already been partially done, when in Table III.2.5 the cost of MOG was transferred in total to the DMG which gets its data from the equipment deployed by MOG. Similarly, in Table III.2.13 below we transfer the costs of the ESG and the CWG to DMG, ISG and ASG (PFZ+TSW).

After apportionment, the total cost of each of these FOUR departments is shown as well as the respective total cost per hour.

TableIII.2.13: Cost sheet forESSO-INCOIS

Col. no.	Group	Annual operational cost Rs.(i)	Total Operational cost per hr. Rs.	Share of ESG cost Rs.(2)	Share of CWG cost Rs.(3)	Total cost Rs. (1+2+3)	Total cost per hr. Rs.	Remarks
1	DMG	411,576,935	175,888	16,899,532	18,645,163	447,121,630	191,078	2340 hrs.
2	ISG	152,772,038	41,970	16,899,532	18,645,163	188,316,733	51,735	3640 hrs.
3	PFZ	106,566,014	19,464	8,449,766	9,322,581	124,338,361	22,710	5475 hrs.
4	TSW	246,433,011	30,160	8,449,766	9,322,581	264,205,358	30,160	8760 hrs.

5. Conclusions

The costing of activities of ESSO-INCOIS, as presented from Table III.2.1 to Table III.2.13, is based on the functional responsibilities of each functional group and its relationship with the final data output given to users in ESSO-INCOIS. The department cost has been computed from the accounting data made available for the study. The figures may be updated to arrive at a cost based on data for the current year. Alternatively, the cost arrived at in Table III.2.13 can be increased by about 20% to include the normal increase in cost of equipment, maintenance and human resources.

We suggest the following steps to bring the costing system into the routine ESSO-INCOIS administrative exercise.

3. Incorporate a costing system that conforms to cost accounting standards as part of the accounting process. Software is available to incorporate a costing system along with an accounting process under ERP.

4. Since the services provided are various, incorporate a system for recording the time spent on executing each service, which can be further split into customer-specific time spent. This step would help significantly in various decisions on pricing the services provided. We suggest introducing Activity Based Costing so that the costs of output-services can be measured accurately, along with information available on the cost of each specific activity or group of homogeneous activities.

Chapter III.3 Note on Guidelines for Pricing Product-Services of ESSO-INCOIS and ESSO-NCMRWF

The decision to charge for product-services has become an integral feature of government agencies, though there are problem of consistency between the pricing policies adopted in different areas and the problem of executing the pricing decisions effectively. In the cases of ESSO-INCOIS and ESSO-NCMRWF also, the problems exist and an appropriate policy framework could only be evolved over the years. The guidelines set out herewith are aimed to recover full cost of the services, though in case of some end-users, who receive the product-services, the charges may not be levying or less than cost-recovery due to specific reasons. At the outset, it must be emphasised here that the decision to charge a price from the buyers of the product-service or to increase the price already being charged, may influence the behaviour of users depending on the elasticity of demand.

The guidelines may be used as a checklist for a policy decision arrive at prices for different product-services of the two agencies under study. Normally, pricing models are based on following principles:

I. Equity:

Levy a charge based on cost incurred for each service in the same fashion across users unless users are categorised into reference groups/governmental agencies.

II. Transaction Costs:

Cost in collecting the tariff levied may overweigh the quantum of tariff itself, in which case it may be prudent not to levy any tariff at all.

III Information:

Information required may vary per customer needs; these require special pricing estimation. Pricing models may differ for customised forecasts which in turn may require specific intellectual inputs necessitating adoption of special pricing models.

IV Type of Beneficiaries and positive externalities:

Positive externalities of the services provided by the agencies should be taken into consideration while deciding on service charges/prices; Beneficiaries can be classified as reference groups (equivalent to government) or others.

V Competition in provision of services:

Some of the product services of the two agencies may face competition from similar services provided by private sector agencies. Prices fixed by the government agencies may influence prices charged by the alternative service providers.

What should be the Price- Illustrative examples

While the points considered above can be the guiding factors for deciding on an objective pricing policy by both the agencies, we present below illustrative examples for arriving at prices for product- services.

1) Illustrative example I:

Charge only Annual Departmental Overheads, if demand is sensitive to prices. For example in case product services of ESSO-INCOIS, the capital costs of equipments and overheads of Establishment Services Group (ESG) and Computer and Web facilities Group (CWG), may be excluded.

For example the cost structure of PFZ, as calculated in the present study, is Table III.3.1:

Table III.3.1: Cost structure of PFZ

S .No.	Cost Heads	Total Cost Rs.(Lakhs)	Annual Cost Rs.(lakhs)
1	Software (3 ARC GIS+4ERDAS+1 ENVI)	79.5	15.5
2	Display Boards-100+FAX	523.4	104.7
3	Dissemination Cost		73.3
4	R&D Cost		170
5	Annual Operation Cost (1-4)		363.9
6	Revenue Expenditure		450.4
7	Operations and Maintenance		106.9
8	Establishment Expenses		9.4
9	Administration Expenses		3.7
10	Proportional ESSO-INCOIS OHCost (6+7+8+9)		570.5
11	Salary to Staff of PFZ		131.2
12	Annual PFZ Cost (5+10+11)		1,065.6
13	Proportionate ESG Cost		84.5
14	Proportionate CWG Cost		93.2
15	Total PFZ Cost (12+13+14)		1,243.3

Item no.10 in the table (sum of items 6-9) plus salaries to Staff of PFZ constitute the departmental overheads cost which in this case is Rs.701 lakhs. The non-Tuna products service-product provided

by PFZ has estimated users of about 100000. The annual cost per user comes to Rs. 701. In the case of fishermen they belong to the reference group, no fee is charged but the cost incurred in providing the service is estimated to be Rs. 701 per fishermen.

2) Illustrated example II: Price on 'Cost plus' basis

For products-services bought by commercial users like profit-making companies or large Ship owners or Consulting Agencies, price charged could exceed the total cost incurred for providing the services. For customised products," Cost plus" pricing policy is found appropriate if no market mechanism exists to determine prices. Under this Policy, we include full costs incurred in providing the service and percentage of the total costs as a margin to reflect on the return on capital. The margin can be the interest rate on Public debts. Depending on the financial viability of the user/s and also the degree of elasticity to price (can be nearly inelastic too, as in the case of users 'Tuna' product-service of PFZ), a suitable rate of return above the total cost can be computed. The agency may also consider factoring in 'intellectual fees' as recommended in the "guidelines on costing for taking up consultancy projects" issued in 2014, in such price decisions. Once the projected cost plus return on capital is estimated, per user fees can be determined by distributing this among the projected number of users.

3) Illustrated example III: Differential cost based prices

Where costs vary by the type of equipments used or vary by location, time or otherwise, differential pricing policy may be fixed for different customers/users. For example, we found that the product services provided by Data Management Group (DMG) use different equipments as base platform for generating data. The pricing of product-services from a specific base equipment would be based on the capital cost of only that equipment and exclude the capital costs of other equipments. However, the overheads of DMG, Salaries to Employees in DMG, and proportionate overheads of ESSO-INCOIS would be added to the specific equipment annual cost, to arrive at the Total Annual cost of providing product-service/s from that specific equipment. Below we present a table showing cost of services of DMG from platforms like Moored Buoys as the base platform equipment and arriving at illustrative prices:

Table III.3.2: Cost of services of DMG

Sl.no.	Platform	Numbers	Annual Total Cost	Price 1-Rs. (Lakhs)	Price 2=Rs. (Lakhs)
1	Wave Rider Buoy	26	39.68	44.44	55.55
2	Tide Gauges	36	679.38	760.91	951.13
3	Drifters	30	442.55	495.66	619.57
4	XBT	3	449.96	503.96	629.94
5	Moored Buoy	15	1311.68	1469.08	1836.35
6	Agro Floats	118	1345.74	1507.23	1884.04

Note: The detailed calculations are given separately in an excel sheet appended in the report

We suggest a policy for periodically reviewing prices once fixed. This is especially necessary in the initial years of arriving at prices for product-services which hitherto had been provided free of any charges. Once the price is fixed and collected from the targeted users, it is necessary to install an appropriate process for recognising changes in cost, demand factors and changes in technology. Demand factors would include changes in composition of buyer-users and their ability to bear charges. Cost estimates should be regularly reviewed and areas for reducing the total costs should be explored. It will be very useful if the accounting system is designed to provide detailed cost calculation for different product-services. Also, regular monitoring is required to identify potential drivers for re-fixing the prices, such as increase in the volume of buyers (this will reduce the per user price charged already) etc. Since the two agencies under the present study are exclusive providers of many a product-services, it is essential to remember that the users/buyers have important part in influencing quality, quantity and therefore the total cost of output-services.

4) Illustrative example IV: Economic Pricing:

For products-services of ESSO-NCMRWF and ESSO-INCOIS, economic costing option can be an option. Under this policy, we include full costs incurred in providing the service, excluding transfer payments such as taxes and duties, if accounting statements provide such details. In other words the principle adopted would be same as that of "cost plus" pricing approach except that the margin added to the "full cost" would be a capital recovery per year per user that would enable ESSO-NCMRWF and ESSO-INCOIS to earn a 12 per cent IRR. The capital recovery per year per user on "economic" investments in 2014/15 prices that need to be added to full cost as margin can be worked from the following table.

Table III.3.3 "Margin" as capital recovery per year per user to earn 12 per cent IRR

A) Gross investments in ESSO-NCMRWF in 2014 prices (Department wise)

1.1	High performance computing (HPC)	Rs 209.64 crore
1.2	Cumulative cost of maintenance	Rs 51.23 crore
1.3	Supporting infrastructure to HPC	Rs 55.22 crore
1.4	National knowledge network	Rs 5.62 crore

B) Gross Investments in ESSO-INCOIS department wise in 2014 prices

2.1	Potential Fishing Zone	Rs 17.09 crore
2.2	Tsunami Storm Surge Warning System	Rs 96.64 crore
2.3	Ocean State Forecast	Rs 4.06 crore
2.4	Data Services	Rs 8.77 crore
2.5	Computational Facilities needed	Rs 13.83 crore

C) Capital Recover per year needed to earn 12% IRR: 0.1275

If the agency considers factoring in "intellectual fees", then the cumulative investments in staff & scientists, knowledge upgradation costs, contribution to monsoon desk should be summed up to compute the "intellectual" fee component for ESSO-NCMRWF. The "intellectual fee" component for ESSO-NCMRWF would be computed on gross investments in human capital in 2014 prices works out to Rs 164 crore as shown below (Table III.3.4). The capital recovery needed per year to account for the intellectual fee is Rs. 21 crore for ESSO-NCMRWF.

Table III.3.4: Gross investments in Human capital and knowledge upgradation to compute intellectual fee

3.1	ESSO-NCMRWF Expenditure on staff salaries	Rs 113.84 crore
3.2	Knowledge upgradation cost	Rs 7.86 crore
3.3	Contribution to WMO	Rs 31.39 crore
3.4	Contribution to Monsoon Desk/UKMO	Rs 10.67 crore

In similar fashion, the cumulative human capital for ESSO-INCOIS in 2014 prices works out to Rs 39.53 crore. The capital recovery needed per year to account for the intellectual fee is Rs. 5 crore for ESSO-INCOIS.

Illustrative Examples of ESSO-INCOIS Product Services

Cost of Product-Services of ISG (Information Services and Oceanographic Services)

ISG provides around 45 product-services. Of these, 24 are general products and balance 21 are customised products. Time spent on providing each service was provided by the ISG group. The time spent consists of two segments, one for the development of the product and the other for routine activities for making the output available for dissemination to the end users/buyers. The development time is assumed to have a shelf life of 3 years, and so development time is divided by 3 to distribute in 3 years. Annual operational time for each of the services listed by the group was also made available. The total time spent for providing a product-service by ISG is thus computed. The ratio of time spent for each product-service over the total time spent on all the product-services of ISG, is taken as the basis for distribution of the total ISG Annual Cost. Thus, the cost of each product- services has been computed and shown in Annexure ISG.

Pricing ISG Product-Services

One of the purposes of computing reasonably accurate cost of the product-services is to fix the price to be charged from the buyers of the services. The decision to charge a price for the product-services ISG, like for any other groups of ESSO-INCOIS, is a discretionary one of the ESSO-INCOIS based on whatever pricing policy it chooses to adopt.

We have given in the note on guidelines for fixing prices of product-services of ESSO-INCOIS & ESSO-NCMRWF, various aspects influencing such pricing decisions. Based on those guidelines we present an illustrative template for pricing ISG Product-services for a year, in Annexure ISG. Following assumptions have been factored in:

1. Price is computed on the basis of produce-services' proportionate Annual Cost of ISG. The Price 1 is cost plus a margin of 12% on cost. Since this is an illustrative template, it is emphasised here that appropriate rate must be fixed in consultation with concerned authorities of the Government, while fixing prices for actual implementation.

2. Price 2 is computed by adding intellectual fees, as notional cost, to the annual incurred cost of ISG. As per "the guidelines of costing for taking-up consultancy projects by ESSO-INCOIS" 2014, the intellectual fees is fixed at the minimum level of 40% for illustration purposes.

We give the product name and the prices arrived in the following table:

Table III.3.5: Pricing of ISG product and services

Product	Price 1 (Rs Lakhs)	Price 2 (Rs Lakhs)	Remarks
Coastal Forecast of Wave & Wind	35.50	44.40	The prices can be rounded off and distributed among chargeable customers, to arrive at the price per customer.
Regional Forecast of Wave & Wind	27.50	34.32	
Real time Validation system for Wave forecasting	68.20	85.28	
Location specific water level forecast	28.71	35.89	
Regional Forecast-Currents, MLD,SST, D20	61.39	76.74	
Location specific wind & wave forecasts	19.26	24.08	
ROMS Temperature, Salinity, Currents profiles	125.67	157.10	
Location specific Forecasts for Sundarbans	45.47	56.84	
Coastal High Resolution Wind Atlas	1.93	2.41	

Note: Price 1 and Price 2, in the above table represent the price including the cost and margin for the respective product-service. Individual price is to be fixed for each customer who is identified as chargeable customer, unless there is just one customer for whom the product was developed and supplied.

Costing of product-services of ASG (Advisory Services and Satellite Oceanography Services Group)

ASG provide two product services, namely PFZ (Potential Fisheries Zone Group) and TSW (Tsunami Warning). Since TSW is a typical product-service focused on warning on the occurrence (or not), it is assumed to be a service to be provided as a responsibility of the Government, without any revenue expectations.

The cost of the other product of ASG, i.e. PFZ & TUNA has been computed based on the time spent by the group for providing these, two product-services. We give below the cost of the two product-services as well illustrated price fixing for both the products. While PFZ is used by about 100000 users, TUNA is used by 50-100 users (potential to increase up to 2500). The users of PFZ are mostly fishermen who have been considered the reference group. No fees are levied on reference group users as such fees form 'transfer payments'.

Table III.3.6: ASG-product and services

Product service	Annual cost-(Rs lakhs)	Price 1 -(Rs lakhs)	Price 2 -(Rs lakhs)
PFZ	621.69	Not levied	Not levied
TUNA	621.69	696.29	870.36

TUNA has about 50-100 current customers with the potential to increase in the number of customers to 2500. Either of the prices computed as illustrations are total prices including cost and margin expected and the same can be distributed among 50-100 customers to arrive at the price to be charged per customer. As we were informed the customers of TUNA are not elastic to price, if charged.

Costing of Product-Services of DMG (Data Management Group)

DMG provides product-services from data derived different platform/sensor. The time spent in providing product-services, platform/sensor wise, is given Annexure DMG. Based on the time spent cost of product-services, platform/sensor wise, have been derived from the total Annual Cost of DMG. The product-services cost is presented in Annexure DMG.

The composition of users of the product-services is quite complex- ranging from users of data given in public domain to industry users, researchers, consultants etc. The ESSO-INCOIS has to take policy decisions to charge differential prices from its varied customers/users of product-services. The products may have to be given free to users who cannot afford or the transaction cost of collection of charges may outweigh the revenue. At the same time there are users like industrial units and consultants who use the products for their private commercial profits. Such commercial users may be charged on "Cost plus" basis or even at a higher price, depending on the degree of negotiations feasible. We suggest pricing policy may be framed for each product-service, based on the guidelines already given above. However, we have made illustrative template to explain the process of price fixation, as shown for product-services of ISG and ASG.

Table III.3.7: Pricing of product services of DMG

Platform	Service	COST-Rs. (Lakhs)	Price 1-Rs. (Lakhs)	Price 2-Rs. (Lakhs)
ARGO & CTD	CTD & ARGO	1,135	1,271	1,589
Drifting buoy	Atmospheric pressure, SST and Ocean currents	21.79	24.40	30.50
XBT	Temperature Profiles	39.34	44.05	55.07
Wave Rider Buoy	Wave Parameters	42.66	47.78	59.72

ESSO-NCMRWF

ESSO-NCMRWF has two products for which the total annual costs had been computed and submitted are taken as the basis for illustrative "cost plus" price fixing mechanism. We have given two illustrations-Price 1 and Price 2.

1. The Price 1 is cost plus margin which is assumed to be 12% on cost. Since this is an illustrative template, it is emphasised here that appropriate rate must be fixed in consultation with concerned authorities of the Government, while fixing prices for actual implementation.

2. Price 2 is computed by adding intellectual fees, as notional cost, to the annual incurred cost of the product. As per "the guidelines of costing for taking-up consultancy projects by ESSO-INCOIS" 2014, the intellectual fees is fixed at the minimum level of 40% for illustration purposes. Product-services costs along with the illustrated prices are presented below:

Product	**Total Annual Cost**	**Price 1**	**Price 2**
1 DA Cycle	9.27	10.39	12.99
4 DA Cycle	37.10	41.56	51.95
10-hr. Forecast	12.36	13.85	17.32

Note: Price 1(Cost + 12%) and Price 2 (cost Plus intellectual fee of 40%), in the above table represent actually the price including the cost and margin expected from the respective product-service. Individual price is to be fixed for each customer who is identified as chargeable customer, unless there is just one customer for whom the product was developed and supplied.

Appendices

Appendix 1

India Crop-wise Area Cultivated (Agriculture Year July 2011–12)

Crop	Area ('000 hectares)			
	Kharif	Rabi	Total	Share in all crops
Paddy	28,067.04	5,001.80	33,068.83	26.94
Jowar	2,928.76	1,063.95	3,992.71	3.25
Bajra	4,250.09	234.69	4,484.77	3.65
Maize	3,738.14	1,361.05	5,099.20	4.15
Ragi	648.88	71.72	720.60	0.59
Wheat	262.15	21,492.28	21,754.43	17.72
Barley	3.96	353.11	357.07	0.29
Small Millet	221.99	8.88	230.87	0.19
Other Cereals	61.44	4.66	66.10	0.05
Gram	391.63	4,472.05	4,863.68	3.96
Tur (Arhar)	1,766.94	435.64	2,202.58	1.79
Urad	1,356.88	361.19	1,718.07	1.4
Moong	798.39	565.97	1,364.36	1.11
Masur	19.51	485.60	505.12	0.41
Horse gram	99.76	57.97	157.73	0.13
Beans (Pulses)	57.46	15.46	72.91	0.06
Peas (Pulses)	11.90	209.72	221.61	0.18
Other Pulses	273.65	255.59	529.24	0.43
Sugarcane	2,427.45	1,191.57	3,619.02	2.95
Palmvriah	0.02	0.03	0.05	0
Other Sugar Crops	0.78	1.17	1.95	0
Pepper (Black)	19.45	29.91	49.37	0.04
Chillies	234.81	131.84	366.65	0.3
Ginger	68.16	43.75	111.90	0.09
Turmeric	43.66	27.76	71.42	0.06
Cardamom (Small)	14.82	10.69	25.51	0.02
Cardamom (Large)	25.60	1.98	27.58	0.02
Betel nut (Areca nut)	283.99	444.69	728.68	0.59
Garlic	11.47	100.80	112.27	0.09
Coriander	5.51	194.84	200.35	0.16
Tamarind	7.07	4.24	11.31	0.01
Cumin Seed	4.60	167.43	172.03	0.14
Fennel/ Anise Seed	1.15	6.51	7.66	0.01
Nutmeg	4.88	5.80	10.68	0.01
Fenugreek	0.01	13.09	13.10	0.01
Cloves	0.06	0.30	0.36	0

Crop	Area ('000 hectares)			
	Kharif	Rabi	Total	Share in all crops
Cocoa	15.56	9.88	25.44	0.02
Betel vine	12.17	13.19	25.37	0.02
Other condiments & Spices	4.85	1.28	6.13	0
Mango	84.98	243.52	328.50	0.27
Orange And Kinnow	7.51	4.03	11.54	0.01
Mosambi	5.01	2.69	7.71	0.01
Lemon/ Acid Lime	11.63	12.26	23.89	0.02
Other citrus fruits	0.06	0.03	0.09	0
Banana	155.13	128.69	283.83	0.23
Table grapes	14.58	6.29	20.87	0.02
Wine grapes (Black)	0.03		0.03	0
Apple	74.82	0.39	75.22	0.06
Pear	6.20	0.02	6.22	0.01
Peach	0.02	0.12	0.14	0
Chiku	2.80	1.82	4.61	0
Papaya	7.91	7.08	14.99	0.01
Guava	7.31	5.64	12.95	0.01
Almond	5.39		5.39	0
Walnut	1.96		1.96	0
Cashew nuts	19.92	65.93	85.84	0.07
Apricot	0.39	0.25	0.65	0
Jackfruit	1.33	2.48	3.81	0
Litchi	1.65	1.39	3.04	0
Pineapple	4.32	3.63	7.95	0.01
Watermelon	3.48	25.21	28.69	0.02
Mulberry (Shahtoot)	14.99	6.49	21.48	0.02
Aonla (Amla)	0.79	0.00	0.79	0
Other Fruits	27.23	17.46	44.69	0.04
Potato	232.21	831.12	1,063.34	0.87
Tapioca (Cassava)	26.45	17.83	44.28	0.04
Sweet Potato	3.55	4.71	8.27	0.01
Yam	7.07	3.29	10.36	0.01
Elephant Foot Yam	2.68	3.14	5.82	0
Colocasia/Arum	6.80	2.29	9.09	0.01
Other Tuber Crops	1.47	0.41	1.88	0
Onion	178.60	203.42	382.02	0.31
Carrot	13.86	15.01	28.88	0.02
Radish	11.80	12.23	24.03	0.02
Beetroot	0.57	2.69	3.26	0

Crop	Area ('000 hectares)			
	Kharif	Rabi	Total	Share in all crops
Turnip (Shalgam)	4.56	0.33	4.88	0
Tomato	151.85	150.24	302.10	0.25
Spinach	6.52	7.41	13.93	0.01
Amaranthus (Chaulai)	1.89	0.05	1.93	0
Cabbage	57.70	92.36	150.06	0.12
Other Leafy Vegetable	64.10	130.87	194.97	0.16
Brinjal	65.49	164.13	229.63	0.19
Peas (Vegetable) (Green)	10.16	71.88	82.04	0.07
Ladies' Fingers (Bhindi)	11.90	52.52	64.42	0.05
Cauliflower	64.46	54.34	118.80	0.1
Cucumber	20.81	34.79	55.60	0.05
Bottle Gourd (Lauki)	7.17	6.56	13.74	0.01
Pumpkin	28.08	29.36	57.44	0.05
Bitter Gourd	8.62	41.13	49.75	0.04
Other Gourds	3.75	6.51	10.26	0.01
Vench (Guar)	61.43	57.92	119.35	0.1
Beans (Green)	45.25	21.80	67.05	0.05
Drumstick	2.75	3.44	6.18	0.01
Green Chillies	32.47	40.23	72.70	0.06
Other Vegetables	77.36	166.46	243.81	0.2
Other Food Crops	78.58	17.91	96.48	0.08
Groundnut	1,950.73	387.98	2,338.71	1.91
Castor seed	411.38	186.72	598.10	0.49
Sesamum (Til)	439.59	225.58	665.17	0.54
Rapeseed & Mustard	83.94	2,983.15	3,067.09	2.5
Linseed	0.32	24.85	25.17	0.02
Coconut	450.86	486.52	937.38	0.76
Sunflower	297.32	179.76	477.08	0.39
Safflower	3.61	55.31	58.91	0.05
Soya bean	6,383.60	51.86	6,435.46	5.24
Niger seed	5.86	0.89	6.75	0.01
Oil Palm	3.03	2.03	5.06	0
Other Oilseeds	159.24	123.54	282.78	0.23
Cotton	7,537.18	1,367.29	8,904.47	7.25
Jute	252.79	38.23	291.02	0.24
Mesta	0.13		0.13	0
Sunhemp	3.81	0.40	4.22	0
Other Fibres	0.73	0.01	0.75	0
Opium	0.04	0.07	0.11	0

Crop	Area ('000 hectares)			
	Kharif	Rabi	Total	Share in all crops
Tobacco	54.74	83.68	138.41	0.11
Other Drugs & Narcotics	0.23	0.39	0.62	0
Guar	424.94	3.77	428.71	0.35
Oats	1.12	6.11	7.23	0.01
Green Manures	13.58	0.61	14.19	0.01
Other Fodder Crops	996.45	1,082.41	2,078.85	1.69
Tea	147.93	154.04	301.97	0.25
Coffee	204.54	201.69	406.23	0.33
Rubber	198.59	166.13	364.72	0.3
Other Plantation Crops	416.59	10.75	427.34	0.35
Orchid	14.96	8.42	23.39	0.02
Rose	1.28	0.74	2.02	0
Gladiolus	0.50	0.29	0.79	0
Marigold	1.12	3.95	5.07	0
Other Flowers	24.98	12.58	37.56	0.03
Moosli	1.06		1.06	0
Other Medicinal Plants	4.29	4.44	8.73	0.01
Mint	4.20	1.85	6.04	0
Menthol	31.04	352.09	383.13	0.31
Eucalyptus	0.85	0.73	1.58	0
Other Aromatic Plants	3.95	0.74	4.69	0
Canes	0.41		0.41	0
Bamboos	18.55	15.09	33.64	0.03
Other Non-Food Crops	2,362.38	41.05	2,403.42	1.96
All Crops	72,806.45	49,949.86	122,756.30	100

Source: NCAER's computation using NSS Round 70 unit-level data.

Appendix 2

Crop	Production (tonnes/ numbers)			
	Kharif	Rabi	Total	Share in all crops
Paddy	91,671,753.60	22,407,683.80	114,079,437.00	19.66
Jowar	6,533,926.20	1,141,896.40	7,675,823.00	1.32
Bajra	5,333,261.30	464,130.70	5,797,392.00	1.00
Maize	7,570,599.30	5,965,018.60	13,535,618.00	2.33
Ragi	703,332.70	135,135.70	838,468.00	0.14
Wheat	333,569.80	61,854,641.70	62,188,212.00	10.72
Barley	8,715.80	431,975.70	440,691.00	0.08
Small Millet	113,109.10	4,543.40	117,652.00	0.02
Other Cereals	90,019.50	5,998.70	96,018.00	0.02
Gram	247,116.00	3,730,061.40	3,977,177.00	0.69
Tur (Arhar)	1,060,069.60	266,496.40	1,326,566.00	0.23
Urad	720,184.70	247,048.50	967,233.00	0.17
Moong	290,459.60	211,117.30	501,577.00	0.09
Masur	14,908.90	415,992.50	430,901.00	0.07
Horse gram	37,834.00	19,468.20	57,302.00	0.01
Beans (Pulses)	39,428.00	9,230.20	48,658.00	0.01
Peas (Pulses)	36,553.10	260,997.80	297,551.00	0.05
Other Pulses	86,676.20	100,331.10	187,007.00	0.03
Sugarcane	134,588,259.20	67,903,087.10	202,491,346.00	34.90
Palmyrah	6,029.20	6,960.00	12,989.00	0.00
Other Sugar Crops	29,322.00	5,840.00	35,162.00	0.01
Pepper (Black)	6,122.40	13,383.00	19,505.00	0.00
Chillies	503,551.50	528,368.70	1,031,920.00	0.18
Ginger	245,660.50	127,969.80	373,630.00	0.06
Turmeric	214,228.10	106,994.10	321,222.00	0.06
Cardamom (Small)	5,690.70	1,892.50	7,583.00	0.00
Cardamom (Large)	3,937.00	1,629.90	5,567.00	0.00
Betel nut (Areca nut)	3,130,347.30	3,803,713.90	6,934,061.00	1.20
Garlic	30,509.50	366,530.60	397,040.00	0.07
Coriander	1,577.00	199,551.40	201,128.00	0.03
Tamarind	2,762.50	7,072.70	9,835.00	0.00
Cumin Seed	1,227.20	87,535.30	88,762.00	0.02
Fennel/ Anise Seed	850.70	2,230.10	3,081.00	0.00
Nutmeg	5,392.40	1,986.60	7,379.00	0.00
Fenugreek	17.10	23,468.70	23,486.00	0.00
Cloves	41.90	1.20	43.00	0.00
Cocoa	11,555.10	3,624.10	15,179.00	0.00

Crop	Production (tonnes/ numbers)			
	Kharif	Rabi	Total	Share in all crops
Betel vine	13,301,415.40	11,916,508.40	25,217,924.00	4.35
Other condiments & Spices	37,211.80	2,675.00	39,887.00	0.01
Mango	590,813.00	1,042,512.40	1,633,325.00	0.28
Orange and Kinnow	140,455.40	99,212.20	239,668.00	0.04
Mosambi	30,932.60	5,422.50	36,355.00	0.01
Lemon/ Acid Lime	226,420.90	178,793.10	405,214.00	0.07
Other citrus Fruits	1,189.30	344.80	1,534.00	0.00
Banana	9,749,138.20	2,866,489.90	12,615,628.00	2.17
Table Grapes	285,239.70	123,565.30	408,805.00	0.07
Wine Grapes (Black)	172.80		173.00	0.00
Apple	1,147,276.40	0.00	1,147,276.00	0.20
Pear	44,582.40	41.50	44,624.00	0.01
Peach	31.90	380.60	413.00	0.00
Chiku	10,825.40	7,927.80	18,753.00	0.00
Papaya	378,537.90	151,674.50	530,212.00	0.09
Guava	91,633.10	67,065.70	158,699.00	0.03
Almond	3,619.60		3,620.00	0.00
Walnut	9,187.00		9,187.00	0.00
Cashew nuts	3,185.50	34,406.60	37,592.00	0.01
Apricot	554.60	392.20	947.00	0.00
Jackfruit	2,306.60	17,321.30	19,628.00	0.00
Litchi	63,136.00	14,450.60	77,587.00	0.01
Pineapple	23,123.10	18,319.00	41,442.00	0.01
Watermelon	35,421.80	199,966.90	235,389.00	0.04
Mulberry (Shahtoot)	14,062.70	4,500.80	18,563.00	0.00
Aonla (Amla)	14,758.60	0.80	14,759.00	0.00
Other Fruits	109,879.40	23,756.40	133,636.00	0.02
Potato	2,070,248.90	12,148,939.50	14,219,188.00	2.45
Tapioca (Cassava)	255,624.50	118,259.70	373,884.00	0.06
Sweet Potato	15,011.40	20,797.30	35,809.00	0.01
Yam	24,261.80	7,183.30	31,445.00	0.01
Elephant Foot Yam	26,390.10	60,628.30	87,018.00	0.01
Colocasia/Arum	19,896.40	8,142.90	28,039.00	0.00
Other Tuber Crops	3,868.40	954.40	4,823.00	0.00
Onion	953,762.20	1,881,438.30	2,835,201.00	0.49
Carrot	77,501.40	82,302.00	159,803.00	0.03
Radish	69,132.00	65,152.40	134,284.00	0.02
Beetroot	5,328.10	59,929.80	65,258.00	0.01
Turnip (Shalgam)	11,534.60	2,168.90	13,703.00	0.00

Crop	Production (tonnes/ numbers)			
	Kharif	Rabi	Total	Share in all crops
Tomato	2,020,398.80	2,210,740.60	4,231,139.00	0.73
Spinach	35,334.40	15,053.50	50,388.00	0.01
Amaranthus (Chaulai)	4,088.80	275.00	4,364.00	0.00
Cabbage	1,256,994.60	841,065.00	2,098,060.00	0.36
Other Leafy Vegetables	218,901.60	565,387.60	784,289.00	0.14
Brinjal	440,773.50	1,101,577.20	1,542,351.00	0.27
Peas (Vegetable) (Green)	43,903.40	260,604.60	304,508.00	0.05
Ladies' Fingers (Bhindi)	50,241.40	182,651.10	232,892.00	0.04
Cauliflower	926,488.50	407,863.00	1,334,351.00	0.23
Cucumber	176,123.50	250,729.60	426,853.00	0.07
Bottle Gourd (Lauki)	59,157.50	93,569.30	152,727.00	0.03
Pumpkin	146,063.60	134,897.60	280,961.00	0.05
Bitter Gourd	58,628.90	53,358.50	111,987.00	0.02
Other Gourds	54,421.30	44,609.70	99,031.00	0.02
Vench (Guar)	37,312.00	8,438.00	45,750.00	0.01
Beans (Green)	96,200.00	132,703.80	228,904.00	0.04
Drumstick	17,530.00	12,902.00	30,432.00	0.01
Green Chillies	146,390.30	170,898.20	317,288.00	0.05
Other Vegetables	403,997.00	834,652.20	1,238,649.00	0.21
Other Food Crop	721,098.50	108,008.70	829,107.00	0.14
Groundnut	1,510,925.30	563,991.10	2,074,916.00	0.36
Castor seed	272,392.40	215,644.00	488,036.00	0.08
Sesamum (Til)	121,888.60	160,316.40	282,205.00	0.05
Rapeseed & Mustard	89,991.00	3,823,888.70	3,913,880.00	0.67
Linseed	24.80	12,072.90	12,098.00	0.00
Coconut	2,366,872.00	2,706,927.50	5,073,799.00	0.87
Sunflower	154,488.70	139,722.50	294,211.00	0.05
Safflower	1,188.60	16,533.30	17,722.00	0.00
Soya bean	7,306,142.40	62,034.50	7,368,177.00	1.27
Niger seed	10,149.20	2,313.60	12,463.00	0.00
Oil Palm	15,361.80	26,464.40	41,826.00	0.01
Other Oilseeds	72,232.90	80,652.50	152,885.00	0.03
Cotton	9,752,116.60	1,156,236.80	10,908,353.00	1.88
Jute	575,959.80	87,829.90	663,790.00	0.11
Mesta	418.50		419.00	0.00
Sunhemp	7,193.20	287.10	7,480.00	0.00
Other Fibres	2,226.10	1,107.80	3,334.00	0.00
Opium	72.70	45.80	118.00	0.00
Tobacco	53,575.80	132,463.60	186,039.00	0.03

Crop	Production (tonnes/ numbers)			
	Kharif	Rabi	Total	Share in all crops
Other Drugs & Narcotics	7,889.30	4,894.30	12,784.00	0.00
Guar	499,677.60	5,348.60	505,026.00	0.09
Oats	17,233.60	26,393.30	43,627.00	0.01
Green Manures	82,458.10	2,246.00	84,704.00	0.01
Other Fodder Crops	19,932,414.40	19,330,689.90	39,263,104.00	6.77
Tea	634,492.90	698,169.30	1,332,662.00	0.23
Coffee	257,395.00	126,488.00	383,883.00	0.07
Rubber	192,709.50	123,230.70	315,940.00	0.05
Other Plantation Crops	333,903.00	157,266.20	491,169.00	0.08
Orchid	117,518.60	29,268.00	146,787.00	0.03
Rose	211,215.30	290,184.60	501,400.00	0.09
Gladiolus	86,595.00	38,550.00	125,145.00	0.02
Marigold	6,168.50	79,800.00	85,969.00	0.01
Other Flowers	186,129.90	127,937.20	314,067.00	0.05
Moosli	353.10		353.00	0.00
Other Medicinal Plants	9,285.10	1,071.20	10,356.00	0.00
Mint	378.30	194.70	573.00	0.00
Menthol	4,593.90	165,839.60	170,433.00	0.03
Eucalyptus	36,974.00	31,401.60	68,376.00	0.01
Other Aromatic Plants	8,989.20	73,290.70	82,280.00	0.01
Canes	16,165.00		16,165.00	0.00
Bamboos	37,126.80	19,503.60	56,630.00	0.01
Other Non-Food Crops	3,487,732.60	967,139.20	4,454,872.00	0.77
All Crops	338,920,935.80	241,236,408.40	580,157,344.00	100.00

Source: NCAER's computation using NSS Round 70 unit-level data.

Appendix 3

Crop	Total Value of Output (Rs. crore)			
	Kharif	Rabi	Total	Share in all crops
Paddy	118,487.30	30,230.20	148,717.00	27.03
Jowar	5,313.70	1,858.10	7,172.00	1.30
Bajra	6,263.10	711.90	6,975.00	1.27
Maize	9,877.60	6,794.90	16,673.00	3.03
Ragi	1,618.70	246.40	1,865.00	0.34
Wheat	740.40	92,457.80	93,198.00	16.94
Barley	8.90	580.10	589.00	0.11
Small Millet	250.50	9.10	260.00	0.05
Other Cereals	167.10	10.10	177.00	0.03
Gram	823.70	11,888.70	12,712.00	2.31
Tur (Arhar)	3,959.10	1,055.90	5,015.00	0.91
Urad	2,251.10	923.20	3,174.00	0.58
Moong	1,167.40	906.60	2,074.00	0.38
Masur	53.50	1,633.50	1,687.00	0.31
Horse gram	125.50	60.90	186.00	0.03
Beans (Pulses)	208.50	22.80	231.00	0.04
Peas (Pulses)	49.20	600.00	649.00	0.12
Other Pulses	533.50	247.40	781.00	0.14
Sugarcane	37,199.20	18,292.20	55,491.00	10.09
Palmyrah	4.80	5.40	10.00	0.00
Other Sugar Crops	2.90	2.30	5.00	0.00
Pepper (Black)	126.30	358.00	484.00	0.09
Chillies	2,365.90	2,688.40	5,054.00	0.92
Ginger	609.90	323.80	934.00	0.17
Turmeric	467.40	279.70	747.00	0.14
Cardamom (Small)	317.50	65.20	383.00	0.07
Cardamom (Large)	123.00	9.80	133.00	0.02
Betel nut (Areca nut)	4,200.30	1,569.30	5,770.00	1.05
Garlic	64.10	847.00	911.00	0.17
Coriander	4.10	819.80	824.00	0.15
Tamarind	14.10	23.00	37.00	0.01
Cumin Seed	15.50	903.40	919.00	0.17
Fennel/ Anise Seed	9.10	13.70	23.00	0.00
Nutmeg	81.20	58.60	140.00	0.03
Fenugreek	0.00	61.20	61.00	0.01
Cloves	2.70	2.00	5.00	0.00
Cocoa	33.70	9.70	43.00	0.01

Crop	Total Value of Output (Rs. crore)			
	Kharif	Rabi	Total	Share in all crops
Betel vine	367.20	306.90	674.00	0.12
Other condiments & Spices	117.30	14.70	132.00	0.02
Mango	545.60	1,552.30	2,098.00	0.38
Orange And Kinnow	59.70	43.80	104.00	0.02
Mosambi	22.50	3.00	26.00	0.00
Lemon/ Acid Lime	27.00	19.20	46.00	0.01
Other citrus fruits	1.00	0.30	1.00	0.00
Banana	2,973.10	1,328.50	4,302.00	0.78
Table Grapes	1,360.30	582.60	1,943.00	0.35
Wine Grapes (Black)	0.80		1.00	0.00
Apple	4,586.50	0.00	4,587.00	0.83
Pear	35.90	0.10	36.00	0.01
Peach	0.20	0.50	1.00	0.00
Chiku	11.60	9.40	21.00	0.00
Papaya	166.20	63.40	230.00	0.04
Guava	61.90	20.20	82.00	0.01
Almond	11.70		12.00	0.00
Walnut	105.60		106.00	0.02
Cashew nuts	78.60	210.90	289.00	0.05
Apricot	2.20	1.20	3.00	0.00
Jackfruit	6.80	22.90	30.00	0.01
Litchi	249.10	10.90	260.00	0.05
Pineapple	27.30	20.10	47.00	0.01
Watermelon	52.90	96.90	150.00	0.03
Mulberry (Shahtoot)	149.40	37.00	186.00	0.03
Aonla (Amla)	23.60	0.00	24.00	0.00
Other Fruits	322.60	96.50	419.00	0.08
Potato	1,489.30	7,003.10	8,492.00	1.54
Tapioca (Cassava)	187.80	96.30	284.00	0.05
Sweet Potato	16.90	25.10	42.00	0.01
Yam	38.00	10.80	49.00	0.01
Elephant Foot Yam	35.80	50.90	87.00	0.02
Colocasia/Arum	37.60	13.90	52.00	0.01
Other Tuber Crops	6.50	1.80	8.00	0.00
Onion	850.50	2,270.60	3,121.00	0.57
Carrot	70.00	127.60	198.00	0.04
Radish	44.10	51.40	96.00	0.02
Beetroot	5.90	36.30	42.00	0.01
Turnip (Shalgam)	10.10	2.30	12.00	0.00

Crop	Total Value of Output (Rs. crore)			
	Kharif	Rabi	Total	Share in all crops
Tomato	1,302.70	2,269.50	3,572.00	0.65
Spinach	20.60	26.30	47.00	0.01
Amaranthus (Chaulai)	4.80	0.50	5.00	0.00
Cabbage	616.50	925.70	1,542.00	0.28
Other Leafy Vegetables	304.60	809.40	1,114.00	0.20
Brinjal	424.80	1,338.60	1,763.00	0.32
Peas (Vegetable) (Green)	79.30	559.80	639.00	0.12
Ladies' Fingers (Bhindi)	62.60	297.30	360.00	0.07
Cauliflower	1,256.00	626.90	1,883.00	0.34
Cucumber	369.90	195.00	565.00	0.10
Bottle Gourd (Lauki)	40.90	77.80	119.00	0.02
Pumpkin	93.60	121.50	215.00	0.04
Bitter Gourd	137.80	80.50	218.00	0.04
Other Gourds	30.90	68.00	99.00	0.02
Vench (Guar)	348.60	58.30	407.00	0.07
Beans (Green)	138.60	248.40	387.00	0.07
Drumstick	51.80	14.20	66.00	0.01
Green Chillies	412.30	317.90	730.00	0.13
Other Vegetables	456.90	789.90	1,247.00	0.23
Other Food Crop	391.90	464.80	857.00	0.16
Groundnut	6,652.90	2,012.80	8,666.00	1.57
Castor seed	891.60	715.50	1,607.00	0.29
Sesamum (Til)	838.70	683.10	1,522.00	0.28
Rapeseed & Mustard	267.70	12,382.80	12,651.00	2.30
Linseed	0.20	38.00	38.00	0.01
Coconut	1,522.90	2,035.60	3,559.00	0.65
Sunflower	539.10	511.20	1,050.00	0.19
Safflower	3.80	54.60	58.00	0.01
Soya bean	22,580.20	188.90	22,769.00	4.14
Niger seed	14.00	3.80	18.00	0.00
Oil Palm	10.30	14.70	25.00	0.00
Other Oilseeds	231.80	302.80	535.00	0.10
Cotton	38,350.50	4,263.60	42,614.00	7.74
Jute	1,253.80	213.00	1,467.00	0.27
Mesta	0.30		0.00	0.00
Sunhemp	18.20	1.00	19.00	0.00
Other Fibres	1.40	0.10	2.00	0.00
Opium	6.40	0.60	7.00	0.00
Tobacco	452.10	1,010.90	1,463.00	0.27

Crop	Total Value of Output (Rs. crore)			
	Kharif	Rabi	Total	Share in all crops
Other Drugs & Narcotics	20.80	1.20	22.00	0.00
Guar	3,239.40	16.60	3,256.00	0.59
Oats	5.20	11.20	16.00	0.00
Green Manures	30.50	3.90	34.00	0.01
Other Fodder Crops	3,378.30	3,409.50	6,788.00	1.23
Tea	2,169.20	1,047.10	3,216.00	0.58
Coffee	1,698.90	815.80	2,515.00	0.46
Rubber	3,178.70	1,997.30	5,176.00	0.94
Other Plantation Crops	170.10	40.30	210.00	0.04
Orchid	181.10	43.30	224.00	0.04
Rose	29.10	40.10	69.00	0.01
Gladiolus	18.40	9.60	28.00	0.01
Marigold	5.40	38.60	44.00	0.01
Other Flowers	247.40	130.10	378.00	0.07
Moosli	41.20		41.00	0.01
Other Medicinal Plants	150.60	20.40	171.00	0.03
Mint	36.50	18.60	55.00	0.01
Menthol	410.10	1,336.70	1,747.00	0.32
Eucalyptus	4.10	4.80	9.00	0.00
Other Aromatic Plant	16.40	5.20	22.00	0.00
Canes	4.10		4.00	0.00
Bamboos	175.00	110.40	285.00	0.05
Other Non-Food Crops	8,557.00	655.50	9,212.00	1.67
All Crops	315,648.10	234,580.80	550,229.00	100.00

Source: NCAER's computation using NSS Round 70 unit-level data.

Appendix 4

Crop	Total Expenses (Rs. crore)			
	Kharif	Rabi	Total	Share in all crops
Paddy	46,022.20	12,342.00	58,364.20	26.73
Jowar	2,063.90	758.60	2,822.50	1.29
Bajra	2,432.70	290.60	2,723.30	1.25
Maize	3,836.60	2,774.20	6,610.70	3.03
Ragi	628.70	100.60	729.30	0.33
Wheat	287.60	37,747.50	38,035.10	17.42
Barley	3.50	236.80	240.30	0.11
Small Millet	97.30	3.70	101.00	0.05
Other Cereals	64.90	4.10	69.00	0.03
Gram	319.90	4,853.80	5,173.70	2.37
Tur (Arhar)	1,537.80	431.10	1,968.90	0.90
Urad	874.40	376.90	1,251.30	0.57
Moong	453.40	370.10	823.60	0.38
Masur	20.80	666.90	687.70	0.31
Horse gram	48.80	24.90	73.60	0.03
Beans (Pulses)	81.00	9.30	90.30	0.04
Peas (Pulses)	19.10	244.90	264.00	0.12
Other Pulses	207.20	101.00	308.20	0.14
Sugarcane	14,448.70	7,468.10	21,916.80	10.04
Palmyrah	1.90	2.20	4.10	0.00
Other Sugar Crops	1.10	1.00	2.10	0.00
Pepper (Black)	49.00	146.20	195.20	0.09
Chillies	919.00	1,097.60	2,016.50	0.92
Ginger	236.90	132.20	369.10	0.17
Turmeric	181.50	114.20	295.80	0.14
Cardamom (Small)	123.30	26.60	150.00	0.07
Cardamom (Large)	47.80	4.00	51.80	0.02
Betel nut (Areca nut)	1,631.40	640.70	2,272.10	1.04
Garlic	24.90	345.80	370.70	0.17
Coriander	1.60	334.70	336.30	0.15
Tamarind	5.50	9.40	14.90	0.01
Cumin Seed	6.00	368.80	374.80	0.17
Fennel/ Anise Seed	3.50	5.60	9.10	0.00
Nutmeg	31.60	23.90	55.50	0.03
Fenugreek	0.00	25.00	25.00	0.01
Cloves	1.10	0.80	1.90	0.00
Cocoa	13.10	3.90	17.00	0.01

Crop	Total Expenses (Rs. crore)			
	Kharif	Rabi	Total	Share in all crops
Betel vine	142.60	125.30	267.90	0.12
Other condiments & Spices	45.60	6.00	51.60	0.02
Mango	211.90	633.80	845.70	0.39
Orange and Kinnow	23.20	17.90	41.10	0.02
Mosambi	8.70	1.20	10.00	0.00
Lemon/ Acid Lime	10.50	7.80	18.30	0.01
Other citrus Fruits	0.40	0.10	0.50	0.00
Banana	1,154.80	542.40	1,697.20	0.78
Table Grapes	528.40	237.80	766.20	0.35
Wine Grapes (Black)	0.30		0.30	0.00
Apple	1,781.50	0.00	1,781.50	0.82
Pear	14.00	0.00	14.00	0.01
Peach	0.10		0.10	0.00
Chiku	4.50	3.80	8.30	0.00
Papaya	64.60	25.90	90.50	0.04
Guava	24.00	8.20	32.30	0.01
Almond	4.60		4.60	0.00
Walnut	41.00		41.00	0.02
Cashew nuts	30.50	86.10	116.60	0.05
Apricot	0.90	0.50	1.30	0.00
Jackfruit	2.60	9.30	12.00	0.01
Litchi	96.70	4.50	101.20	0.05
Pineapple	10.60	8.20	18.80	0.01
Watermelon	20.50	39.50	60.10	0.03
Mulberry (Shahtoot)	58.00	15.10	73.10	0.03
Aonla (Amla)	9.20	0.00	9.20	0.00
Other Fruits	125.30	39.40	164.70	0.08
Potato	578.40	2,859.10	3,437.60	1.57
Tapioca (Cassava)	72.90	39.30	112.20	0.05
Sweet Potato	6.60	10.30	16.80	0.01
Yam	14.80	4.40	19.20	0.01
Elephant Foot Yam	13.90	20.80	34.70	0.02
Colocasia/Arum	14.60	5.70	20.30	0.01
Other Tuber Crops	2.50	0.70	3.30	0.00
Onion	330.30	927.00	1,257.40	0.58
Carrot	27.20	52.10	79.30	0.04
Radish	17.10	21.00	38.10	0.02
Beetroot	2.30	14.80	17.10	0.01
Turnip (Shalgam)	3.90	0.90	4.90	0.00

Crop	Total Expenses (Rs. crore)			
	Kharif	Rabi	Total	Share in all crops
Tomato	506.00	926.60	1,432.50	0.66
Spinach	8.00	10.70	18.70	0.01
Amaranthus (Chaulai)	1.80	0.20	2.00	0.00
Cabbage	239.50	378.00	617.40	0.28
Other Leafy Vegetable	118.30	330.40	448.80	0.21
Brinjal	165.00	546.50	711.50	0.33
Peas (Vegetable) (Green)	30.80	228.50	259.30	0.12
Ladies' Fingers (Bhindi)	24.30	121.40	145.70	0.07
Cauliflower	487.90	255.90	743.80	0.34
Cucumber	143.70	79.60	223.30	0.10
Bottle Gourd (Lauki)	15.90	31.80	47.70	0.02
Pumpkin	36.30	49.60	86.00	0.04
Bitter Gourd	53.50	32.90	86.40	0.04
Other Gourds	12.00	27.80	39.70	0.02
Vench (Guar)	135.40	23.80	159.20	0.07
Beans (Green)	53.80	101.40	155.20	0.07
Drumstick	20.10	5.80	25.90	0.01
Green Chillies	160.10	129.80	289.90	0.13
Other Vegetables	177.50	322.50	500.00	0.23
Other Food Crop	152.20	189.80	342.00	0.16
Groundnut	2,584.10	821.80	3,405.80	1.56
Castor seed	346.30	292.10	638.40	0.29
Sesamum (Til)	325.80	278.90	604.70	0.28
Rapeseed & Mustard	104.00	5,055.50	5,159.50	2.36
Linseed	0.10	15.50	15.60	0.01
Coconut	591.50	831.10	1,422.60	0.65
Sunflower	209.40	208.70	418.10	0.19
Safflower	1.50	22.30	23.80	0.01
Soya bean	8,770.50	77.10	8,847.60	4.05
Niger seed	5.40	1.60	7.00	0.00
Oil Palm	4.00	6.00	10.00	0.00
Other Oilseeds	90.10	123.60	213.70	0.10
Cotton	14,895.90	1,740.70	16,636.60	7.62
Jute	487.00	87.00	574.00	0.26
Mesta	0.10		0.10	0.00
Sunhemp	7.10	0.40	7.50	0.00
Other Fibres	0.60	0.00	0.60	0.00
Opium	2.50	0.20	2.70	0.00
Tobacco	175.60	412.70	588.30	0.27

Crop	Total Expenses (Rs. crore)			
	Kharif	Rabi	Total	Share in all crops
Other Drugs & Narcotics	8.10	0.50	8.60	0.00
Guar	1,258.20	6.80	1,265.00	0.58
Oats	2.00	4.60	6.60	0.00
Green Manures	11.80	1.60	13.40	0.01
Other Fodder Crops	1,312.20	1,392.00	2,704.20	1.24
Tea	842.50	427.50	1,270.10	0.58
Coffee	659.90	333.10	993.00	0.45
Rubber	1,234.60	815.40	2,050.10	0.94
Other Plantation Crops	66.10	16.50	82.50	0.04
Orchid	70.30	17.70	88.00	0.04
Rose	11.30	16.40	27.70	0.01
Gladiolus	7.10	3.90	11.10	0.01
Marigold	2.10	15.80	17.80	0.01
Other Flowers	96.10	53.10	149.20	0.07
Moosli	16.00		16.00	0.01
Other Medicinal Plants	58.50	8.30	66.80	0.03
Mint	14.20	7.60	21.80	0.01
Menthol	159.30	545.70	705.00	0.32
Eucalyptus	1.60	1.90	3.60	0.00
Other Aromatic Plant	6.40	2.10	8.50	0.00
Canes	1.60		1.60	0.00
Bamboos	68.00	45.10	113.10	0.05
Other Non-Food Crops	3,323.70	267.60	3,591.30	1.64
All Crops	122,602.30	95,771.70	218,374.00	100.00

Source: NCAER's computation using NSS Round 70 unit-level data.

Appendix 5

Crop	Net Profit (in Rs crore)			
	Kharif	Rabi	Total	Share in all crops
Paddy	72,465.10	17,888.20	90,353.30	27.23
Jowar	3,249.80	1,099.50	4,349.30	1.31
Bajra	3,830.40	421.20	4,251.70	1.28
Maize	6,041.00	4,020.80	10,061.80	3.03
Ragi	990.00	145.80	1,135.80	0.34
Wheat	452.80	54,710.30	55,163.10	16.62
Barley	5.40	343.30	348.70	0.11
Small Millet	153.20	5.40	158.60	0.05
Other Cereals	102.20	6.00	108.20	0.03
Gram	503.70	7,034.90	7,538.70	2.27
Tur (Arhar)	2,421.40	624.80	3,046.20	0.92
Urad	1,376.80	546.30	1,923.10	0.58
Moong	714.00	536.40	1,250.40	0.38
Masur	32.70	966.60	999.40	0.30
Horse gram	76.80	36.00	112.80	0.03
Beans (Pulses)	127.50	13.50	141.00	0.04
Peas (Pulses)	30.10	355.00	385.10	0.12
Other Pulses	326.30	146.40	472.70	0.14
Sugarcane	22,750.50	10,824.10	33,574.60	10.12
Palmyrah	2.90	3.20	6.10	0.00
Other Sugar Crops	1.80	1.40	3.20	0.00
Pepper (Black)	77.20	211.90	289.10	0.09
Chillies	1,447.00	1,590.80	3,037.80	0.92
Ginger	373.00	191.60	564.60	0.17
Turmeric	285.90	165.50	451.40	0.14
Cardamom (Small)	194.20	38.60	232.80	0.07
Cardamom (Large)	75.20	5.80	81.00	0.02
Betel nut (Areca nut)	2,568.80	928.60	3,497.40	1.05
Garlic	39.20	501.20	540.40	0.16
Coriander	2.50	485.10	487.60	0.15
Tamarind	8.60	13.60	22.20	0.01
Cumin Seed	9.50	534.60	544.00	0.16
Fennel/ Anise Seed	5.60	8.10	13.70	0.00
Nutmeg	49.70	34.70	84.40	0.03
Fenugreek	0.00	36.20	36.20	0.01
Cloves	1.70	1.20	2.80	0.00
Cocoa	20.60	5.70	26.30	0.01

Crop	Net Profit (in Rs crore)			
	Kharif	Rabi	Total	Share in all crops
Betel vine	224.50	181.60	406.20	0.12
Other condiments & Spices	71.80	8.70	80.50	0.02
Mango	333.70	918.60	1,252.20	0.38
Orange and Kinnow	36.50	25.90	62.40	0.02
Mosambi	13.80	1.80	15.60	0.00
Lemon/ Acid Lime	16.50	11.40	27.90	0.01
Other citrus Fruits	0.60	0.20	0.80	0.00
Banana	1,818.30	786.10	2,604.40	0.78
Table Grapes	831.90	344.70	1,176.70	0.35
Wine Grapes (Black)	0.50	0.00	0.50	0.00
Apple	2,805.00	0.00	2,805.00	0.85
Pear	22.00	0.10	22.00	0.01
Peach	0.10	0.50	0.60	0.00
Chiku	7.10	5.60	12.70	0.00
Papaya	101.70	37.50	139.20	0.04
Guava	37.80	12.00	49.80	0.02
Almond	7.20	0.00	7.20	0.00
Walnut	64.60	0.00	64.60	0.02
Cashew nuts	48.10	124.80	172.80	0.05
Apricot	1.40	0.70	2.10	0.00
Jackfruit	4.20	13.50	17.70	0.01
Litchi	152.30	6.50	158.80	0.05
Pineapple	16.70	11.90	28.60	0.01
Watermelon	32.30	57.30	89.70	0.03
Mulberry (Shahtoot)	91.40	21.90	113.30	0.03
Aonla (Amla)	14.40	0.00	14.40	0.00
Other Fruits	197.30	57.10	254.40	0.08
Potato	910.80	4,144.00	5,054.80	1.52
Tapioca (Cassava)	114.80	57.00	171.80	0.05
Sweet Potato	10.40	14.90	25.20	0.01
Yam	23.20	6.40	29.60	0.01
Elephant Foot Yam	21.90	30.10	52.00	0.02
Colocasia/Arum	23.00	8.20	31.20	0.01
Other Tuber Crops	4.00	1.10	5.10	0.00
Onion	520.10	1,343.60	1,863.70	0.56
Carrot	42.80	75.50	118.30	0.04
Radish	27.00	30.40	57.40	0.02
Beetroot	3.60	21.50	25.10	0.01

Crop	Net Profit (in Rs crore)			
	Kharif	Rabi	Total	Share in all crops
Turnip (Shalgam)	6.20	1.40	7.60	0.00
Tomato	796.70	1,342.90	2,139.70	0.64
Spinach	12.60	15.60	28.20	0.01
Amaranthus (Chaulai)	2.90	0.30	3.20	0.00
Cabbage	377.10	547.80	924.90	0.28
Other Leafy Vegetable	186.30	478.90	665.20	0.20
Brinjal	259.80	792.10	1,051.90	0.32
Peas (Vegetable) (Green)	48.50	331.30	379.70	0.11
Ladies' Fingers (Bhindi)	38.30	175.90	214.20	0.06
Cauliflower	768.20	370.90	1,139.10	0.34
Cucumber	226.20	115.40	341.60	0.10
Bottle Gourd (Lauki)	25.00	46.00	71.10	0.02
Pumpkin	57.20	71.90	129.10	0.04
Bitter Gourd	84.30	47.70	132.00	0.04
Other Gourds	18.90	40.20	59.10	0.02
Vench (Guar)	213.20	34.50	247.70	0.07
Beans (Green)	84.70	147.00	231.70	0.07
Drumstick	31.70	8.40	40.00	0.01
Green Chillies	252.20	188.10	440.30	0.13
Other Vegetables	279.40	467.40	746.90	0.23
Other Food Crop	239.70	275.00	514.70	0.16
Groundnut	4,068.80	1,191.00	5,259.80	1.58
Castor seed	545.30	423.40	968.70	0.29
Sesamum (Til)	513.00	404.20	917.20	0.28
Rapeseed & Mustard	163.80	7,327.30	7,491.00	2.26
Linseed	0.10	22.50	22.60	0.01
Coconut	931.40	1,204.50	2,135.90	0.64
Sunflower	329.70	302.50	632.20	0.19
Safflower	2.30	32.30	34.60	0.01
Soya bean	13,809.70	111.80	13,921.50	4.20
Niger seed	8.60	2.30	10.80	0.00
Oil Palm	6.30	8.70	15.00	0.00
Other Oilseeds	141.80	179.20	321.00	0.10
Cotton	23,454.60	2,522.90	25,977.50	7.83
Jute	766.80	126.00	892.90	0.27
Mesta	0.20	0.00	0.20	0.00
Sunhemp	11.10	0.60	11.70	0.00
Other Fibres	0.90	0.00	0.90	0.00

Crop	Net Profit (in Rs crore)			
	Kharif	Rabi	Total	Share in all crops
Opium	3.90	0.30	4.20	0.00
Tobacco	276.50	598.20	874.60	0.26
Other Drugs & Narcotics	12.70	0.70	13.50	0.00
Guar	1,981.20	9.80	1,991.00	0.60
Oats	3.20	6.60	9.80	0.00
Green Manures	18.60	2.30	20.90	0.01
Other Fodder Crops	2,066.10	2,017.50	4,083.60	1.23
Tea	1,326.70	619.60	1,946.30	0.59
Coffee	1,039.10	482.70	1,521.80	0.46
Rubber	1,944.00	1,181.90	3,125.90	0.94
Other Plantation Crops	104.00	23.90	127.90	0.04
Orchid	110.70	25.60	136.30	0.04
Rose	17.80	23.70	41.50	0.01
Gladiolus	11.20	5.70	16.90	0.01
Marigold	3.30	22.80	26.10	0.01
Other Flowers	151.30	77.00	228.30	0.07
Moosli	25.20	0.00	25.20	0.01
Other Medicinal Plant	92.10	12.10	104.20	0.03
Mint	22.30	11.00	33.40	0.01
Menthol	250.80	791.00	1,041.80	0.31
Eucalyptus	2.50	2.80	5.40	0.00
Other Aromatic Plant	10.00	3.10	13.10	0.00
Canes	2.50	0.00	2.50	0.00
Bamboos	107.00	65.30	172.40	0.05
Other Non-Food Crops	5,233.30	387.90	5,621.20	1.69
All Crops	193,045.80	138,809.20	331,854.90	100.00

Source: NCAER's computation using NSS Round 70 unit-level data.

Appendix 6

Crop	Net Profit from crop cultivation	Profit due to weather information as % of Net Profit	Net profit due to weather information	Crop-wise % share of net profit due to weather information in total net profit due to weather information
Wheat	55,163.10	25%	13,790.80	18.67%
Paddy	90,353.30	15%	13,553.00	18.35%
Sugarcane	33,574.60	25%	8,393.60	11.37%
Cotton	25,977.50	25%	6,494.40	8.79%
Soya bean	13,921.50	25%	3,480.40	4.71%
Maize	10,061.80	25%	2,515.40	3.41%
Gram	7,538.70	25%	1,884.70	2.55%
Rapeseed & Mustard	7,491.00	25%	1,872.80	2.54%
Other Non-Food Crops	5,621.20	25%	1,405.30	1.90%
Groundnut	5,259.80	25%	1,315.00	1.78%
Potato	5,054.80	25%	1,263.70	1.71%
Jowar	4,349.30	25%	1,087.30	1.47%
Bajra	4,251.70	25%	1,062.90	1.44%
Other Fodder Crops	4,083.60	25%	1,020.90	1.38%
Betel nut (Areca nut)	3,497.40	25%	874.30	1.18%
Rubber	3,125.90	25%	781.50	1.06%
Tur (Arhar)	3,046.20	25%	761.50	1.03%
Chillies	3,037.80	25%	759.40	1.03%
Apple	2,805.00	25%	701.30	0.95%
Banana	2,604.40	25%	651.10	0.88%
Tomato	2,139.70	25%	534.90	0.72%
Coconut	2,135.90	25%	534.00	0.72%
Guar	1,991.00	25%	497.70	0.67%
Tea	1,946.30	25%	486.60	0.66%
Urad	1,923.10	25%	480.80	0.65%
Onion	1,863.70	25%	465.90	0.63%
Other crops	28,800.40	25%	7,182.80	9.73%
All Crops	331,854.90	25%	73,852.10	100.00%

Source: NCAER's computation using NSS Round 70 unit-level data.

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