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Estimating loss and damage from climate-induced disasters: An evaluation using ICRIER 'Prakriti' Model

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**ESTIMATING LOSS AND
DAMAGE FROM CLIMATE-
INDUCED DISASTERS: AN
EVALUATION USING ICRIER
'PRAKRITI' MODEL**

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SAJAL JAIN
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MAY 2024

422

WORKING
PAPER

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Abstract

Data shows that there has been a five-fold increase in the number of climate-related disasters that the world has witnessed over the last fifty years. Just between 2000 and 2019, 7,348 reported disasters caused 1.23 million deaths, affecting a population of 4.03 billion and causing economic losses to the tune of USD 2.97 trillion. Studies have also shown that quick-onset disasters such as floods, typhoons, and cyclones have resulted in more damages and loss of lives in the past two decades in the Asia Pacific region compared to other parts of the world (Neef & Pauli, 2021). The increasing frequency of climate-induced disasters and the rising magnitude of accompanying damages worldwide underlines the need to focus on disaster risk reduction and management responses.

Focussing specifically on India, the Emergency Events Database (EM-DAT) pertaining to natural disasters and their related damage costs for the period of 1990-2022 shows that the nation was among the worst affected countries in the world. The data suggests that floods and storms featured as the top two natural disasters in India between 1990 and 2022, comprising 53% and 27% respectively, while also accounting for the highest share of damage costs at 63.10% and 31.52% respectively. It is, therefore, critical to understand the havoc that each such instance wreaks on the economy and how best to increase the systemic adaptive capacity to meet the same. The present paper tries to contribute to the literature by estimating the direct and indirect impacts of disasters for certain case studies of floods and cyclone incidences in India. The paper builds the case for standardizing disaster reporting frameworks and also expounds on the need for integrating technologies in disaster management for constructing climate-resilient infrastructure.

Using the ICRIER *Prakriti* Disaster Management Model, a regional input-output (RIO) model to study the impact of disasters on local businesses and the economy, the paper assesses two disaster-affected states of India- Assam (flooding) and Andhra Pradesh (cyclones). The modelling exercise highlighted that even though the states differ in terms of the direct impact experienced (with Andhra Pradesh being affected twice as much), the indirect impacts were found to be manifold. Three key results emerge from the analysis. First, cyclone instances in Andhra Pradesh led to a loss of 1.53% in value of output in 2018-19, which is expected to rise in the future, as both the intensity and frequency of cyclones would increase with climate change. Second, despite its high direct losses, Assam was relatively much less affected when the loss of assets by private entities was accounted for. This may be reflective of the high annual frequency of flooding incidences in the state, and the state's high resilience towards this risk. Third, the analysis of the two states revealed distinct loss profiles influenced by their developmental patterns, with Andhra Pradesh experiencing significant losses in the chemical sector, whereas Assam's losses were mainly concentrated in water supply, rubber and plastics, and textiles industries.

Keywords: Disasters, Input-output model

JEL classification: Q54, R15, C63

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Estimating loss and damage from climate-induced disasters: An Evaluation using ICRIER 'Prakriti' Model

Amrita Goldar^{1,2}, Sajal Jain³ and Diya Dasgupta⁴

1. Introduction

According to the World Meteorological Organization (WMO), there has been a five-fold increase in the number of climate-related disasters that the world has witnessed over the last fifty years.⁵ This has become more pronounced in the recent past, as is evident from the series of instances such as the cyclones in Myanmar (*Mocha*) and south east Africa (*Freddy*); floods in China, Libya, and India; wildfires in Greece and Hawaii, etc., that took place in 2023 alone!

A study conducted by UNDDR & CRED (2020) provides a comparative analysis between the periods of 1980-1999 and 2000-2019 that highlights that there has been a marked increase in the number of disasters.⁶ In particular, the former period saw 4,212 disasters being reported, causing 1.19 million deaths, affecting 3.25 billion people, and resulting in economic losses worth USD 1.63 trillion. The corresponding figures for the period of 2000-2019 were 7,348 reported disasters, 1.23 million deaths, 4.03 billion affected population, and economic losses to the tune of USD 2.97 trillion. Studies have also shown that quick onset disasters such as floods, typhoons, and cyclones have resulted in more damages and loss of lives in the past two decades in the Asia Pacific region as compared to other parts of the world (Neef & Pauli 2021).

Specifically in the case of India, a report by the Centre for Science and Environment reveals that in the first nine months of 2022, the country has experienced at least one disaster in one or more parts of the country in the form of cyclones, floods, landslides, heatwaves or cold waves (CSE 2022).

The increasing frequency of climate-induced disasters and the rising magnitude of accompanying damages worldwide underlines the need to focus on disaster risk reduction and management responses. This paper aims to estimate the impacts of climate-induced quick-onset disasters in the case of two Indian states. It makes use of both a case study as well

as a modelling approach to estimate loss and damages at the state level. Further, it also elaborates on the role of technology in securing benefits resulting from climate-resilient infrastructure.

2. Policy relevance & research objective

Policy Relevance

The issue of loss and damage (L&D) is not new and international deliberations centred around this concept have continued to take place, ever since the release of the COP 13 Bali Action Plan, albeit with no avail. Discussions gained momentum with the release of the Warsaw International Mechanism for loss and damage (2013) and the inclusion of L&D under *Article 8* of the Paris Agreement (2015). However, it was only during the COP discussions in 2022 that countries successfully reached an agreement for establishing a new funding arrangement that would aid developing countries that are vulnerable to climate change impacts.

The funds are expected to be used to deal with both economic and non-economic losses associated with slow onset as well as extreme weather events. Moreover, the decision to set up a Transnational Committee that would be tasked with overseeing and guiding the operations of the aforementioned fund and submit its recommendations to the COP was also made (UNFCCC 2022).

Research Objective

Studies in the past have adopted various approaches to examine the impact of climate-induced disasters in India. These include geospatial analysis (Tripathi et al. (2019); Mishra et al. (2022)), damage cost approach (Bahinipati & Venkatachalam (2016); Patankar (2019)) econometric modelling (Panwar & Sen (2019); Amarasinghe et al. (2020)) and so on. While most studies have focused on estimating the direct impact of disasters, the current paper adds to

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5 Available at: <https://www.bbc.com/news/science-environment-58396975>. Accessed on April 14, 2023.

6 Includes geophysical, hydrological, meteorological, and climatological disasters

the existing body of literature by adopting a regional input-output (IO) modelling framework that captures both direct and indirect impacts of climate-induced disasters, particularly floods, and cyclones in select Indian states. Specifically, the model helps examine how losses in one sector have ripple effects across sectors.

Further, while identifying sources to finance L&D is critical, it is equally important to formulate methodologies for explaining ‘needs’ and to recognize areas where the said funds would be channelized. This paper provides an illustrative example of one such methodology that may be used for estimating needs as far as economic losses are considered. Moreover, given that countries such as India comprise varied climatological units, a more granular analysis at the sub-national level is needed. The current paper focuses on the two states of Assam and Andhra Pradesh in India for estimating and analyzing the economic losses and costs incurred in situations of unplanned climate impacts like disasters. The same approach may also be undertaken for other states within the country.

The structure of the paper is as follows. While Sections I and II provide the background and highlight the policy relevance & research objective, damage cost estimates and the case study analysis are

presented in Section III. Section IV expounds on the modelling framework and the results, followed by the recommendations and conclusion in Sections V and VI, respectively.

3. Damage costs and case study analysis

EM-DAT Data Analysis

The Emergency Events Database (EM-DAT), developed by the Centre for Research on Epidemiology of Disasters (CRED), was relied upon to collate data pertaining to natural disasters and their related damage costs for the period of 1990-2022.⁷ For the purpose of this paper, climatological, hydrological, and meteorological disasters have been included, and the disaster subtypes subsumed within the aforementioned categories have been presented in Annexure I Table A.1.

The EM-DAT database has been used to identify the disasters, regions, and instances on which the present study focuses on. With respect to the share of damage costs by disasters in India, floods and storms stand out with a share of 63.10% and 31.52%, respectively. Likewise, in terms of frequency of occurrences, floods, and storms feature as the top most recurrent disasters in the country.

Table 1: Adjusted Damage Costs due to Natural Disasters in India between 1990-2022 (in ‘000 USD)

Disasters	India
Floods	102,392,665
Drought	7,851,001
Extreme Temperature (Cold/heat wave)	589,198
Landslide	77,378
Storm	51,145,887
Wildfire	0
Glacial Lake Outburst	210,000
Total	162,266,129

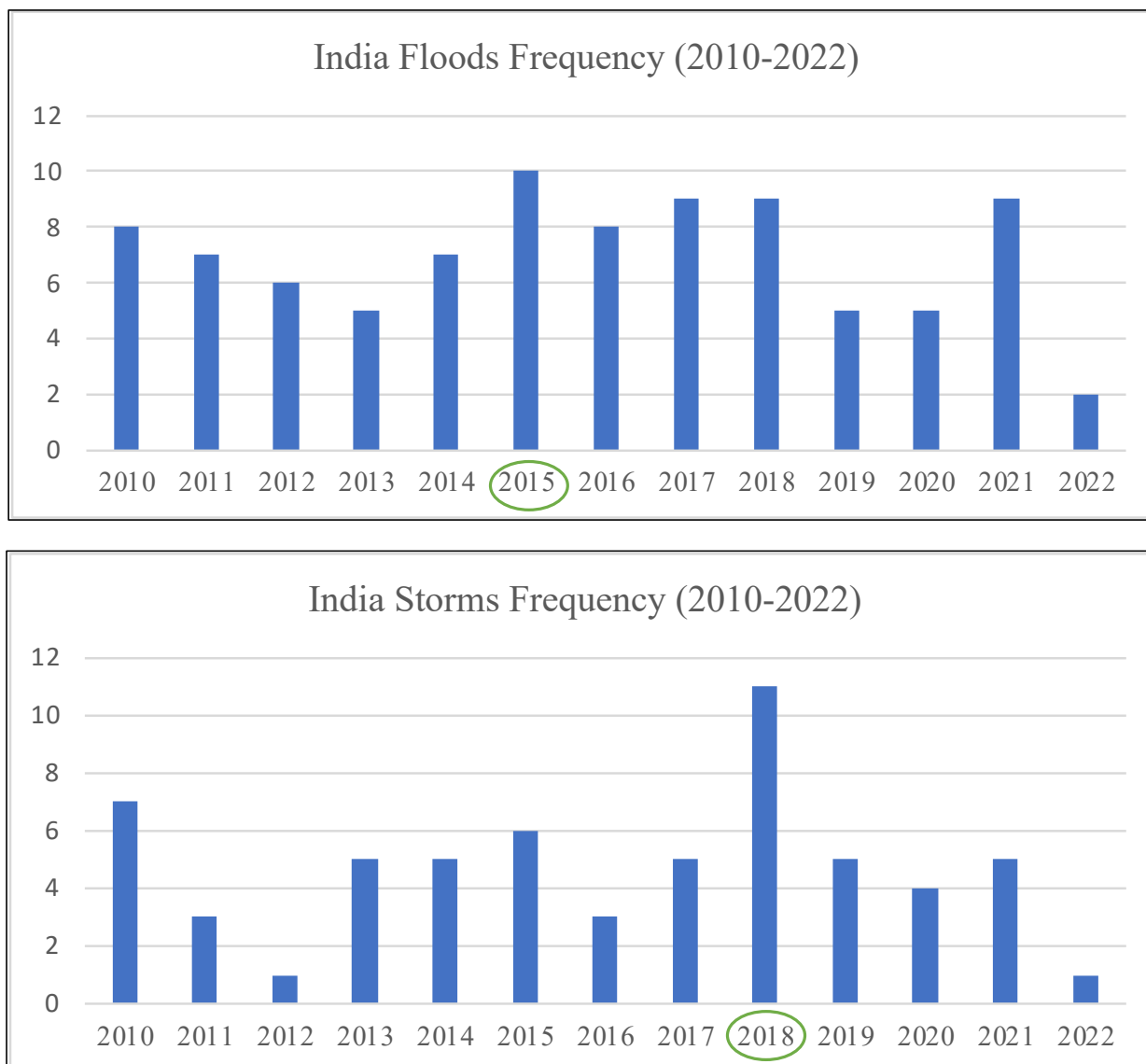
Source: Adapted from Goldar et al. (2023)

Having circled in on the disaster for the analysis, the next step was identifying the region and the exact instance that would be dealt with in detail. For doing the same, the period of focus was narrowed down to 2010-2020, with the understanding that disaster impact data would not be available for the selected regions if the year was too far back. Thus, within

this specified time period, the year recording the maximum frequency of floods and storms in India was identified. These have been indicated in Figure 1. This was followed by identifying regions in India that have experienced the maximum number of occurrences of the said disasters.

⁷ Based on data as on September 8, 2022.

Figure 1: Frequency of occurrences of floods and storms in India



Source: Authors' construction using EMDAT (2022)

At the country level, a general rule of thumb for selecting the region for analysis was that (a) it should feature within the list of top two/three to have experienced the maximum episodes of the disaster in question between 1990-2022 and (b) in 2010-2022, it should have recorded the maximum number of occurrences as well. For example, in the case of floods, Assam recorded a total of 57 episodes between 1990-2022, and in 2015, out of the 10 occurrences in India in that year, 4 were in Assam itself. Details of this region and instance selection exercise have been

presented in Table A.2 in Annexure I.

Disaster Case Studies: Storms and Floods

Based on the data collected from the EMDAT database, an extensive analysis was undertaken to study the impact of disasters in select regions of India (refer to Table 2) and quantify their direct and indirect monetary impact. The numbers obtained were validated through grey literature and other secondary sources.

Table 2: Selected regions for case study analysis

Country	Disaster	State/Province of Focus	Frequency in State/Province of focus during 1990-2022
India	Storms	Andhra Pradesh	34
	Floods	Assam	57

Source: Authors' construction using EM-DAT Data

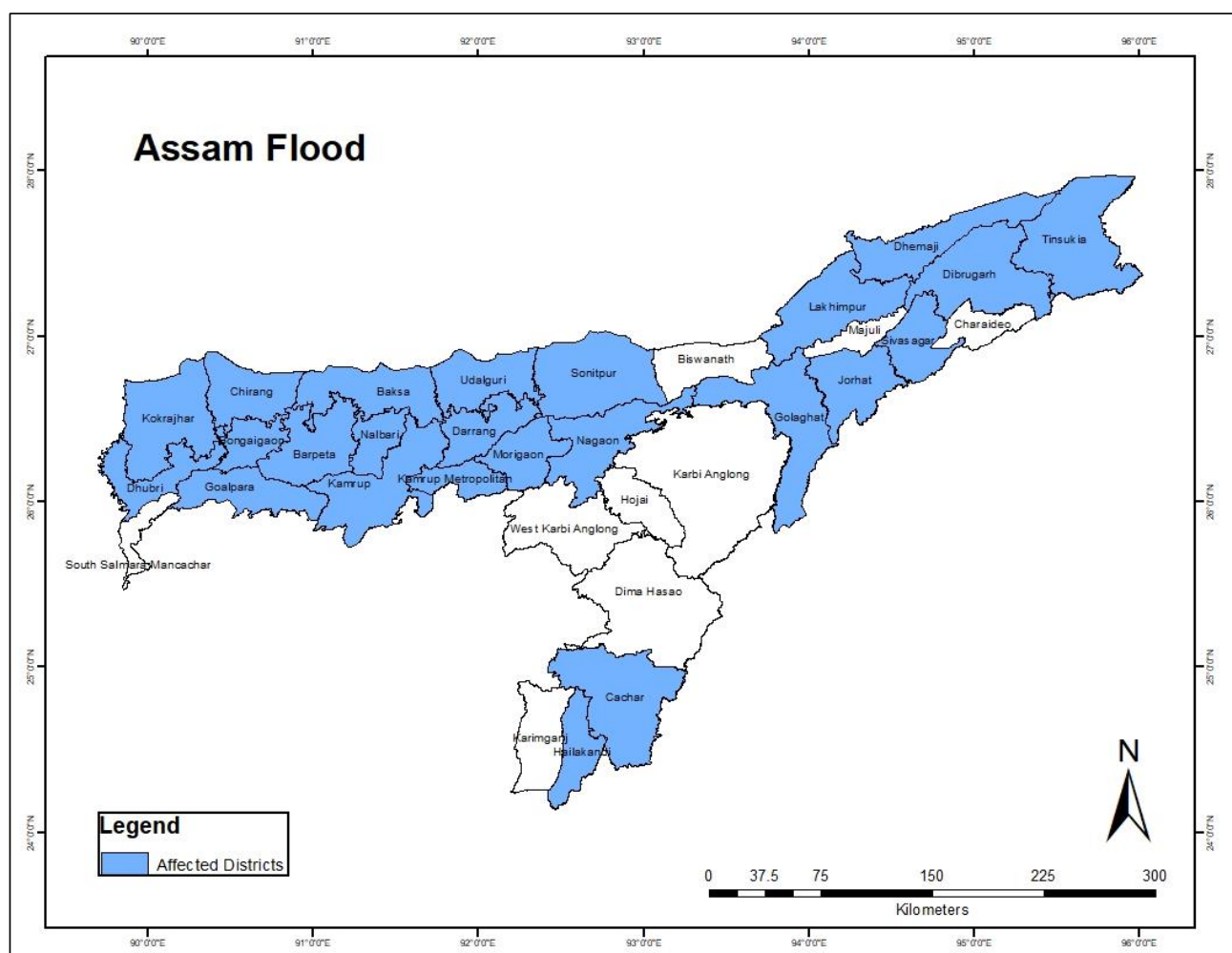
(a) Floods

- Assam, India (2015)

State disaster vulnerability: The state of Assam represents a unique problem with respect to flooding and erosion, both in terms of the duration and extent of flood damages and the magnitude of erosion. According to the assessment carried out by the *Rashtriya Barh Ayog*, roughly 39.58% of the total land in Assam is flood-prone, which translates into 9.4% of India's flood-prone area (10.2% of the total land area of the country) (Government of Assam n.d.). Both natural and anthropogenic factors contribute to the state's flood risk. Similarly, high population growth rates resulting from both immigration and high birth rates have led to the creation of unplanned settlements, increased deforestation, urban development activities in low-lying areas, etc., which negatively impacts the state's vulnerability to floods (ASDMA 2011).

Origin and damage caused: Torrential rains of 2015 led to an increase in the water levels beyond the danger mark at *Brahmaputra* and its tributaries, which in turn resulted in the breaching of embankments, followed by flash floods. The state of Assam witnessed five waves of floods in the period of June-September, wrecking-havoc across 25 districts, causing damages to property, crops, loss of human lives and livestock. Figure 2 depicts the affected districts in the state. The map was generated using ArcGIS 10.6 software, representing the affected districts in blue. Close to 36.67 lakh individuals spread across 4763 villages were recorded to have been affected, along with 66 deaths being reported. Moreover, 3.388 lakh hectares of cropped area suffered damages, approximately 6058 mix of *pucca* and *kutchha* houses were severely damaged, while 57,429 houses (including huts) withstood partial destruction. Additionally, the state witnessed embankment breaches, damage to roads, bridges, culverts, *anganwadi* centres, irrigation canals, school buildings, etc. Details of the same have been presented in Table 3.

Figure 2: Affected districts during Assam Floods



Source: Authors' construction; generated in ArcGIS 10.6 software

Table 3: Damages to Infrastructure and Livestock in Assam floods, 2015

S No.	Damages	Quantity
1	Number of breaches in embankments	46
2	Number of structures of the Water Resource Department damaged	237
3	Number of damaged and breached roads, bridges and culverts	1868
(a)	<i>Number of Roads damaged and breached</i>	1145
(b)	<i>Number of bridges damaged</i>	375
(c)	<i>Number of culverts damaged</i>	348
4	Number of Anganwadi centres fully or partially damaged	4930
5	Number of school buildings damaged	2530
6	Number of irrigation canals damaged	147
7	Number of livestock affected (large animals)	2488
8	Number of miltch/draught animals lost	12030
(a)	<i>Cow</i>	183
(b)	<i>Buffalo</i>	20
(c)	<i>Goat</i>	1207
(d)	<i>Pig</i>	937
(e)	<i>Bullock</i>	57
(f)	<i>Calf</i>	84
(g)	<i>Poultry</i>	9542

Source: Adapted from Flood Memorandum Report (2015), Government of Assam

Relief measures and rescue operations: Search and rescue operations were carried out by the State Disaster Response Force (SDRF), National Disaster Response Force (NDRF), and the army. 984 relief camps across 20 districts were set up, serving 6,76,205 inmates. Relief items distributed by the government included rice, dal, mustard oil, salt, gur, baby food, animal fodder, tarpaulin candles, blankets, mosquito nets, etc. With respect to the role of Non-Governmental Organizations (NGOs), charitable organizations, and civil society, there was active participation by humanitarian agencies such as Oxfam India, Christian Aid, Caritas India, Dan Church, Doctors For You, Adventist Development & Relief Agency (ADRA), etc. to name a few. Interventions carried out by them were coordinated by IAG Assam and Sphere India. These included but were not limited to setting up health camps, distribution of medicines, chlorine tablets, hygiene kits, dignity kits, provisioning of water filters, WASH promotion and awareness, and so on (Inter-Agency Group Assam 2015).

Financial Assistance: As per the proceedings of the State Executive Committee of the State Disaster Management Authority (SDMA) of Assam, a total requirement of INR 1523.79 crore was sought from the centre and subsequently approved for submission to the Ministry of Home Affairs (ASDMA 2015). The financial assistance requested covered a multitude of elements, such as providing gratuitous relief, agricultural assistance, replacement of animals, conducting search & and rescue operations, and repairing & restoring houses and infrastructure. Details of the same have been presented in Annexure I in Table A.3. It is pertinent to mention here that the amount is likely to be an underestimate of the actual expenditure involved as it does not clearly specify the state's own spending towards relief measures.⁸

(b) Storms

- **Andhra Pradesh, India: Cyclones (2018)**

State disaster vulnerability: It was estimated that between 1891 and 2020, India witnessed over 130 severe category cyclonic storms, with 313 cyclones

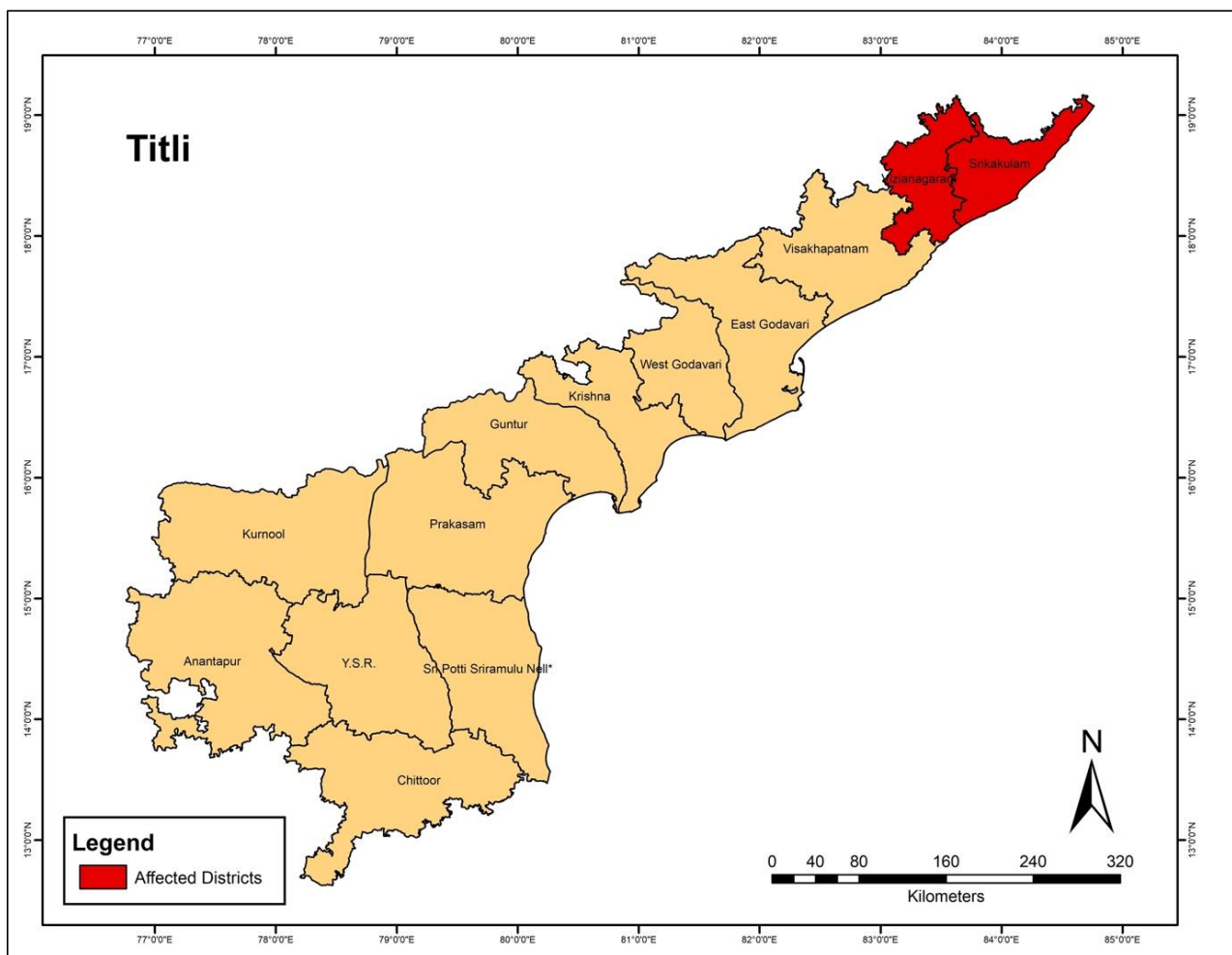
⁸ This conclusion is drawn based on the understanding that each state in India has a designated State Disaster Relief Fund (SDRF) for which funds are allocated by the centre and the state in the ratio of 90:10. In the event that the said fund is exhausted, states can seek additional financial assistance from the centre following a formal submission of memorandum and assessment conducted by an inter-ministerial central team. While the total SDRF of Assam for 2015-16 was INR 460 crore, since the funds are not allocated calamity wise, it is difficult to ascertain what portion of the same was directed towards flood relief. Moreover, SDRF funds can only be used for providing relief measures and not for compensation of losses suffered or claimed (Ministry of Home Affairs 2018).

crossing the eastern and western coasts of the country. Of these, within the eastern coast, the state of Andhra Pradesh was witness to the second-highest number of cyclones in the said period (Parida, Chowdhury and Sahoo 2021). According to the Andhra Pradesh SDMA, on average the state is at risk of at least one cyclone each year, with moderate to severe intensity cyclones occurring every two to three years. A significant portion of the state's population, approximately 2.9 million, is at risk from cyclones, given that 3.3 million of the population is located within a distance of 5 km from the coastline. This therefore, increases the damage probability of any disaster surging from the sea for the state.

Origin and damage caused: In 2018, Andhra Pradesh witnessed two major cyclones, namely, *Titli* and *Phethai*, the former being categorized as a 'very severe' cyclone, causing significant damage to life,

infrastructure, and crops. As per the Andhra Pradesh SDMA (2020), the cyclone extended to 8 districts, causing considerable damage in the two districts of Srikakulam and Vizianagaram, as depicted in Figure 3 (map was generated using the ArcGIS 10.6 software, and the affected districts have been represented in red). Having made landfall near Palasa in the Srikakulam district, Cyclone *Titli* affected a population of 16.83 lakh, with the death toll standing at 14 human and 62,913 livestock losses (AP SDMA 2020). It disrupted road and telecommunication networks and water supply, while also uprooting several electrical poles. The floodwaters inundated homes, forcing inhabitants to live without food and drinking water for more than 48 hours (Sphere India 2018). A detailed summary of damages is provided in Table 4. The total estimated loss for the state due to the cyclone stood at INR 539.52 crores (AP SDMA 2020).

Figure 3: Affected districts of Andhra Pradesh during Cyclone *Titli*



Source: Authors' construction; generated in ArcGIS 10.6 software

Table 4: Loss and damage in Andhra Pradesh due to Cyclone *Titli*

S No.	Damages	Value
1	Number of districts affected	2
2	Number of villages affected	1441
3	Number of deaths due to the cyclone	14
4	Total Population affected	16.83 lakh
5	Number of relief camps and shelters set up	47
6	No. of medical camps	100
	<i>Chlorine tablets distributed</i>	20,000
	<i>Medical officers deployed</i>	30
	<i>Paramedics</i>	220
7	Number of inmates in relief camps	5700
8	Crop area affected	1.40 lakh hectare
9	No. of houses damages	50120
10	Livestock loss	62913
11	Number of milch/draught animals lost	42831
	<i>Big Cattle</i>	328
	<i>Small Animals (Sheep and Goats)</i>	1030
	<i>Calves</i>	40
	<i>Poultry birds</i>	41433
12	Total estimated loss	₹539.52 crore

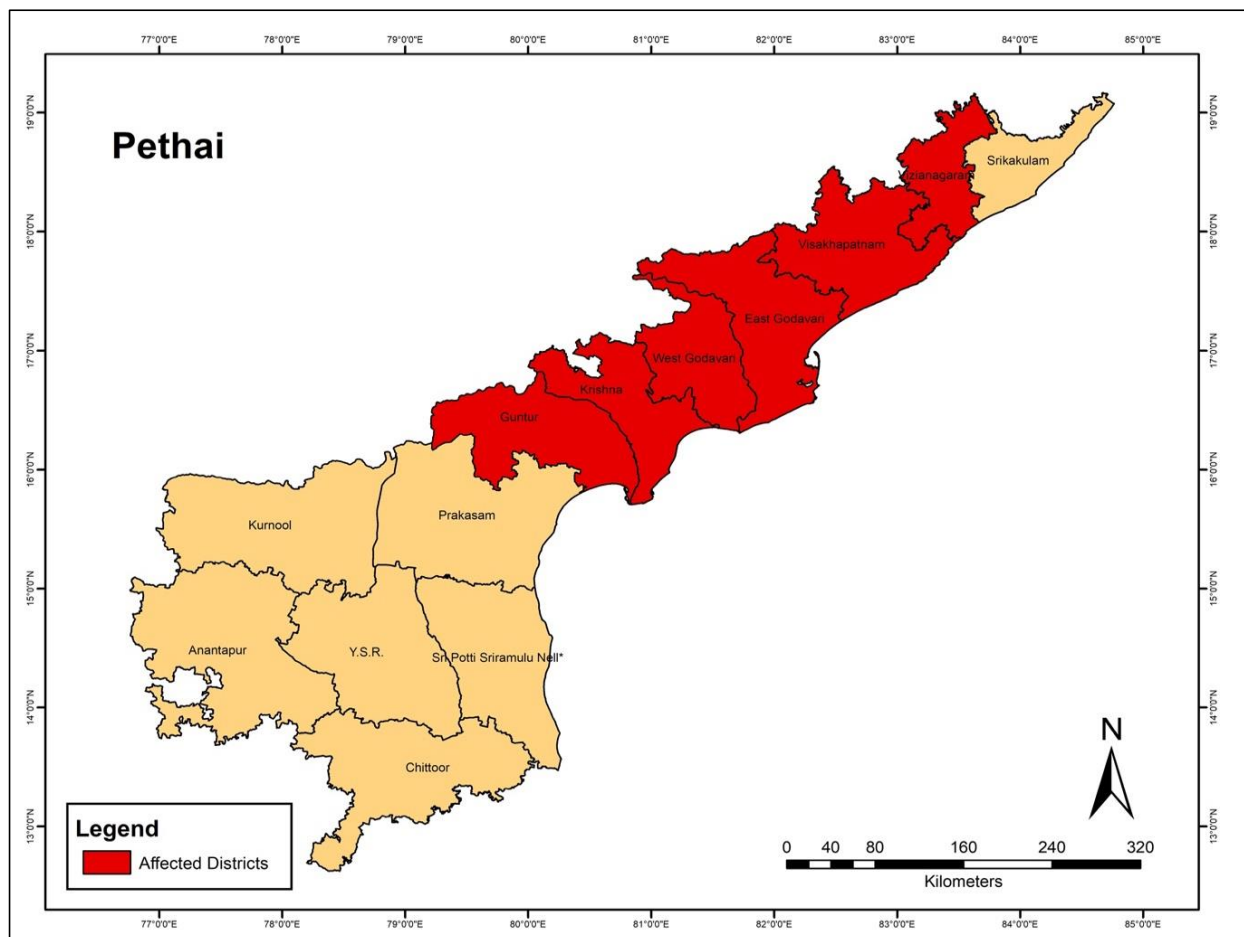
Source: Authors' compilation from different grey literature and secondary sources

In comparison, Cyclone *Phethai* resulted in considerably lesser damage. It occurred in December 2018, making landfall near Katrenikona, East Godavri district of the state. The cyclone affected over 7.96 lakh persons spanning six districts, namely, East Godavri, West Godavri, Krishna, Visakhapatnam, Vijayanagaram, and Guntur (AP SDMA 2020), as shown in Figure 4 (affected districts are represented in red).

Although it was classified as a 'severe' category cyclonic storm, the reported damages were relatively limited. Very heavy rainfall in the range of 200 mm,

168 mm, and 166 mm across different affected districts was reported (Rao and Mohammed 2018). About 205 houses were reported to have incurred damages, in addition to damages or disruption to electricity, road, rail, and air infrastructure services (AP SDMA 2020; Teja 2018). A detailed summary of damages is provided in Table 5. The total estimated loss for the state due to the cyclone stood at INR 94.38 crores (AP SDMA 2020). It is worth mentioning that the data available on damages caused by the two storms in the state (as provided in Tables 4 and 5) does not cover the same factors due to a lack of consistent information from official government sources.

Figure 4: Affected districts of Andhra Pradesh during Cyclone *Phethai*



Source: Authors' construction; generated in ArcGIS 10.6 software

Table 5: Loss and damage in Andhra Pradesh due to Cyclone *Phethai*

S No.	Damages	Value
1	Number of districts affected	6
2	Number of <i>mandals</i> affected	140
3	Number of deaths due to the cyclone	1
4	Number of relief centres	533
5	No. of health centres	878
6	No. of mobile towers damaged	12,094
7	Number of people in relief centres	57,892
8	Crop area affected	10.3 lakh hectare
9	Loss in Horticulture	₹1,647 lakh
10	Horticulture crop	Greater than 10,000 hectares
11	Rice	11,711 hectares
12	Maize	7,025 hectares
13	Dal	2,296 hectares
14	Tobacco	1,221 hectares
15	Sunflower	566 hectares
16	Sugarcane	394.8 hectares
17	No. of houses damaged	205
18	Population affected	7.96 lakh
19	Total estimated loss	₹94.38 crore

Source: Authors' compilation from different grey literature and secondary sources

Relief measures and rescue operations: During Cyclone *Titli*, the state government reacted promptly, with 47 relief camps being set up housing about 5,700 people. In addition, 100 medical camps with medical officers and paramedics were also put in place to attend to the affected people (Sphere India 2018). The state government ensured that food and drinking water, civil supplies were distributed and also worked towards the restoration of electricity supply and communication networks (Reliefweb 2018). Further, rescue operations were initiated by both, the SDRF and the NDRF, with support from the AP Fire Services department. The SDRF deployed 401 personnel and 5 boats, along with 2 satellite phones, and distributed 157 life jackets. Similarly, the NDRF deployed 6 teams, with 185 personnel and, 18 rubber boats, and 2 satellite phones, and distributed 300 life jackets.

During Cyclone *Phethai*, 533 relief centres were setup (Real Time Governance Society (RTGS) 2018), housing about 57,892 persons (Rao and Mohammed 2018) across the affected districts. In addition, 878 health centres were set up, which recorded 28 cases of diarrhea in Visakhapatnam (Real Time Governance Society (RTGS) 2018). The state responded swiftly and deployed 16 teams of Andhra Pradesh Disaster Response and Fire Services in and around Rajamahendravaram (Express Web Desk 2018), while another 9 teams (of 5 members each) in West Godavari district (Express Web Desk 2018) and 47 teams in East Godavari district (Teja 2018), for road clearance. Additionally, as part of disaster preparedness, NDRF, SDRF, and naval helicopters were kept on standby along with 10,000 government employees (Teja 2018).

Financial Assistance: The state government had submitted a memorandum to the Ministry of Home Affairs seeking financial assistance of INR 1330.67 crore following the aftermath of Cyclone *Titli*. After the evaluation of spot damages conducted by the Inter-Ministerial Central Team (IMCT), an amount of INR 539.52 crore was released from the NDRF. In addition, the Indian government also provided the state with INR 458.1 crore as a Central share of SDRF for relief management necessitated by natural disasters during 2018 (Ministry of Home Affairs 2018). Further, the state government announced several financial relief measures, as depicted in Table A.4 in Annexure I.

4. Modelling

Disaster dismantles the economic system. Its effect is not just limited to the havoc caused directly but disrupts the functioning of the economy as a by-product of the event. While previous sections have delved into the known impacts of disasters, there are two critical gaps:

1. Details about losses to industrial production processes is either missing or scanty. As information is collated largely from government sources and grey literature, it revolves around people affected, lives lost, damages to crops, livestock, and public infrastructure.
2. The focus is inordinately on direct damages, but there is loss transmission across the supply chain as an industry gets hit by a natural calamity. Deriving information on such consequent effects is difficult as it spans over a longer time period and also affects regions other than the one struck by disaster.

Past papers like Hallegatte (2008; 2015), Ranger et al. (2011), Lenzen et al. (2019) have discussed that in order to get a closer estimate of adaptation finance required after a disaster, it is crucial to take into account the indirect effects such as impacts on the supply chain, the employment structure, the taxation system, the housing services and industrial production. The present paper attempts to contribute to literature by presenting a case study where direct and indirect (backward-linkages) impacts of disasters are estimated for the aforementioned flooding and cyclone incidences in India.

(a) Literature review

Literature shows these indirect effects and the pace with which the economy reaches its pre-disaster state can be estimated using modelling tools. Different models like IO, Supply-Use Table (SUT) and Computable General Equilibrium (CGE) modelling are usually employed to fulfil these objectives. Haines and Jiang (2001), Bockarjova et al. (2004), Cochrane (2004), Okuyama et al. (2004) assess the impact of disasters using different forms of IO models. However, these studies could not track the supply-side shocks of the event. While Rose et al. (1997) and Okuyama et al. (2004) estimated the backward effects of the disaster using the final demand changes, Galbusera and Giannopoulos (2018) discussed two static “demand-driven” and “supply-driven” IO models with regard to post-disaster recovery. Li et al. (2022) using CGE

modelling allowed flexibility in the economic system through changes in responses from the producer's and consumer's side.

Hallegatte (2015) discusses the incongruity in the economic losses deduced from IO and CGE modelling owing to the differences in the dynamic setting which restricts the adjustment of variable factors. The paper studies the immediate and the dynamic adaptive capacity of the economy after a disaster, taking into account the interest rate, reconstruction duration and the spill-over effects and concludes that the ideal management is possible only if indirect losses and the adaptive capacity are incorporated in the analysis. Li et al. (2022) use a dynamic model and study various recovery factors such as the reconstruction funds, Government Relief funds and Insurance schemes prevailing for the damages caused due to typhoons. However, using insurance claims and tracking the data for insurance is challenging for a developing country like India as insurance diffusion is less than 1% (Patankar 2019) for disasters and this might not account for the total direct and indirect loss and damages caused by the event.

Oosterhaven and Többen (2017) compare the pre and post-disaster scenarios and evaluate the indirect losses of the economy when hit by floods in Germany in 2013 using a multi-regional supply-use model. Hallegatte (2008), Wu et al. (2012) and Ranger et al. (2011) using Adaptive Regional Input-Output (ARIO) model estimated the disaster-related indirect losses in production, backward and forward effects within the economic system and the span over which the economic actors adapt to the changes so that they behave as in the pre-disaster state.

The present paper employs a RIO model and modifies it like Lenzen et al. (2019) and Steenge and Bockarjova (2007), as it is believed that disasters leave a localized impact and it is incorrect to estimate it at a national level. The state-level model takes into account the impact of disasters on local businesses. However, the caveat is that the model looks into the backward effects of disasters and the forward effects are not enumerated due to the unavailability of data. Future iterations of the present model will try to incorporate both backward as well as forward linkages of direct disaster impacts, making it similar to the ARIO model discussed above. The methodology for the state IO table follows the methodology used for constructing the Regional Environmental General Equilibrium Model for India (REGEMI) as used in Bussolo et al. (2003). The RIOs are constructed for the base year

2018-19 for two disaster-affected states of India - Assam and Andhra Pradesh.

They are created using the national input-output transactions table (IOTT) prepared by Chaudhuri, Pratap, & Pohit (2024), with modifications made in the sectoral classification (37 sectors) and disaggregation based on available state parameters (refer to Annexure III for sectoral classification used in the model).

(b) Modelling Framework

As mentioned previously, the framework of the model adopted in this paper is based on the lines as discussed in Lenzen et al. (2019). The present model estimates the indirect impact of disasters on reductions in industry output and thus, consumption possibilities. This reduction is estimated by the creation of a gamma matrix, which is a diagonal matrix of fractions Γ_i indicating a reduction in production possibilities following a disaster. Using the methodology as suggested by Lenzen et al. (2019), data for the annualized value of infrastructure losses have been collated: (a) from statements on public infrastructure losses (Annexure IV), and (b) from losses in value of capital (specifically, plant and machinery, and building) following the flood or cyclone incidence computed using Annual Survey of Industries (ASI). The reduction in output is then translated into reduction in consumption following a linear optimization framework.

This information on direct damages from the cyclone and flood incidences was then translated into annualized values assuming different asset lives and no salvage value (refer to Annexure IV for more detail). This was followed by computing what Lenzen et al. (2019) call, productivity of capital (or π), and multiplying these with the annualised asset losses, annual production loss values were calculated. Thereafter the gamma matrix, or the matrix containing production loss coefficients for each of the affected sectors, is calculated by dividing the derived production losses in each RIO sector by the value of output in the baseline period.

In matrix notation, the new reduced value of output of sector I for sectors 1,...,N can be noted as:

The total economic output is taken as a function of output of individual sectors:

$$\tilde{y} = (I - \Gamma) y_0$$

where y_0 is the original economic output value. Here Γ is a diagonal matrix of sectoral loss coefficients following the disaster and I is the identity matrix.

This reduction in production is then mirrored in the economy as a reduction in consumption possibilities post-disaster. The methodology used from this point onwards marks a departure from what is suggested by Lenzen et al. (2019) and the framework suggested by Steenge and Bockarjova (2007) instead. To compute new lowered consumption possibility, the new (and lower) economic output is pre-multiplied by the IO technology coefficient matrix called A , i.e.

$$\tilde{x} = (I - \Gamma) A y_0$$

where A is the technology coefficient matrix derived from the RIO.

Consumption levels lowered due to disasters can be seen as: $x_1 = x_0 - \Delta x$. Transmitting this reduction through the economy, i.e., as losses in value added and employment: $\Delta Q = q(I - A)^{-1} \Delta x$, and $\Delta E = e(I - A)^{-1} \Delta x$ where q and e are coefficient matrices of value added and employment. This will have subsequent backward effects on the economy starting from immediate job and value-added losses borne by producers, subsequent losses of suppliers, suppliers of suppliers, and so on for upstream production streams.

(c) Modelling results

Based on the modelling analysis conducted, it was found that the loss in output following cyclones in Andhra Pradesh cost the state 1.53% loss in production capabilities. The corresponding figures for Assam showed a loss of just 0.11% in production value. It is noteworthy that the magnitude of difference between the official statements released by the governments of Andhra Pradesh and Assam was not that high. However, once the private sector losses were accounted for, this difference was amplified to

a great extent. Three clear results emerge from this:

- While the cyclone instances in Andhra Pradesh led to a loss of 1.53% in value of output in 2018-19, it is expected to rise in the future, as both the intensity and frequency of cyclones would increase with climate change.
- Assam, despite its high direct losses, was relatively much less affected when the loss of assets by private entities was accounted for. This may be reflective of the high annual frequency of flooding incidences in the state, and the state's high resilience towards this risk.
- The two states analysed showed a very different profile of losses, mostly due to their different developmental patterns. For Andhra Pradesh, while the chemical sector was the hardest hit, similar losses for the state of Assam were not observed. In Assam, the sectors most adversely affected included water supply, rubber and plastics, and textiles.

Converting this loss in production capacity into reduction in intermediate consumption also shows a similar picture, though the extent of impact varies. The reduction in intermediate consumption in Assam is to the extent of 56754 lakh or 0.18% of the total. The figure for Andhra Pradesh is much higher at 20,77,912 lakh or a reduction of 2.91% of the total. By its very design, the sectoral storylines for this variable remain the same as that of production losses (Annexure V).

Amplifying the contractionary impacts of input reduction and transmitting it through the economy by multiplying the Leontief Inverse with the contraction shows the magnitude of changes that could potentially result from the calamity. Our results indicate that while there remains a similar wide variance between the states when value added impacts are looked at, the difference shrinks considerably in the case of employment impacts.

Table 6: Total Impact of Disasters on VA and Employment in Assam and Andhra Pradesh (INR Lakhs)

Component	State	Baseline	Post-Disaster	Difference	Difference (in %)
Value Added	Andhra Pradesh	79817560	77739647	-2077912	-2.60%
	Assam	28214800	28158106	-56694	-0.20%
Employment	Andhra Pradesh	19494153	18854140	-640013	-3.28%
	Assam	8844445	8555386	-289059	-3.27%

Source: Authors' Computation

It however needs to be flagged here that in the normal course of events, such a stark reaction would be an exception rather than the norm. A contraction in input availability would more often than not be met by importing from the rest of the state, country, or the world. There is also rationing that could happen that controls production, final demand from households and industries, and short-term prices. Thus, in future iterations of the model, all of these rational decision-making elements of economic agents would be introduced to make the model as realistic as possible.

Another important takeaway from the model is that even with a similar magnitude of climate-induced disasters, states may be affected very differently depending largely on their own in-built resiliency mechanisms, nature and status of development, governance models, etc. This is worth investigating and would be attempted in future iterations of the model as well.

5. Recommendations

1. The need for a standardised framework for disaster reporting

The EM-DAT database analysis highlights some of the many existing gaps in disaster impact reporting. The issues of limited data availability, or lack of uniform standards followed in reporting damage/loss numbers were observed to remain common across countries. The availability of fragmented information will make it difficult to conduct any in-depth further impact analysis. Moreover, the lack of coherence in reporting formats, both within and across countries, can make claims for relief measures or loss and damage finance difficult to assess. This would have a direct bearing on the challenges to channelise adaptation funds. A few recommendations that could be adopted to facilitate the process have been elaborated upon below:

- a) *Standardisation in reporting of post-disaster impacts, across disasters, countries as well as sub-national regions*

An internationally accepted uniform structure of reporting post-disaster impacts will help to homogenise the criteria for the collection of information. While the Post-Disaster Needs Assessment (PDNA) framework does exist to make post-disaster reporting of damages, losses, etc., a uniform application of the same is not observed. PDNA is an internationally accepted methodology for

determining physical damages, economic losses, and expenses required to address recovery requirements following a natural calamity, through a government-led procedure. It helps in planning recovery and reconstruction, and allocation of government aid for the same (NDMA 2022). A well-executed strategy for implementation will enable thorough investigation and analysis to formulate recovery plans for the country as well as in drawing comparisons across sub-national regions and other countries. Furthermore, the comparisons will aid in learning from the experiences of other countries and understanding what might have worked in one region/country, etc. in better management of a disaster.

As climate-induced disasters become more frequent, the importance of disaster management is increasingly being recognized in the international context as well. However, while it had remained a critical point of discussion, a specific focus on the same was missing for the longest time. This changed with the launch of the Disaster Risk Reduction (DRR) Working Group by the Indian G20 Presidency in December 2022, to encourage collective action. Reflecting the theme of the presidency of 'Vasudhaiva Kutumbakam' – 'One Earth, One Family, One Future', the newly formed DRR working group acknowledges the importance of collaborative action to help prevent hazards from turning into disasters, as well as securing significant loss reductions (NDMA n.d.). The working groups recognise five priority areas, covering Global Coverage of Early Warning Systems, Disaster, and Climate Resilient Infrastructure, Financing Framework for Disaster Risk Reduction, Disaster Response System, and the Ecosystem-based Approach to DRR. Among other related avenues, the consensus of the group reaffirmed their commitment to the Sendai Framework for Disaster Risk Reduction 2015-2030. In addition, the working group also emphasised on strengthening of national and global disaster preparedness, recovery, rehabilitation, and reconstruction systems (PIB 2023). The establishment of the DRR working group can serve as a crucial milestone towards development of effective agreed upon guidelines for the management and evaluation of post-disaster losses and impacts, making such reporting a part of a voluntary disclosure mechanism.

These comparable disclosures could also have the added benefits of speeding up relief measures from international sources, settlement of claims from insurance companies and encouraging greater uptake of risk management financial instruments like

insurance by private entities.

b) Constitution of a committee for designing of the framework

Effective implementation of a uniform structure of post-disaster reporting will not be an easy task. This will require proper analysis and thorough understanding of all aspects of post-disaster reporting as well as management, while maintaining proper sensitivity of the subject matter. Similar to various committees and institutions that help countries or regions to prepare for a disaster, a committee constituting of international organizations such as the Coalition for Disaster Resilient Infrastructure (CDRI), to look after and design the essential parameters for post-disaster reporting, working in close coordination with member countries, sub-national disaster management authorities etc, could be critical. The consortium may prove to be useful for designing the framework based on diverse localised factors and could oversee effective implementation of the same through the help of local authorities in different countries.

c) Encourage greater role of insurance companies and the private sector in post-disaster impact reporting

Based on the in-depth study of grey literature and other secondary sources, it was found that much of the reported damages numbers publicly available were restricted to a few sectors including losses to government or public infrastructure. Furthermore, as the data was primarily provided by government sources, there was a considerable underestimation of the damages incurred. Two significant components where under-reporting was noted were the following: damages to physical capital in local industries, and damage to houses and other amenities for the residential sector. While this information can potentially be collated through claims made to insurance companies, the same is not readily available in the public domain.

It is important to note that the EMDAT database focuses on reporting damages that measure immediate direct impacts mostly on human suffering and damage to crops, livestock, and property. However, due to the long-term impact of losses in physical capital on incomes generated in subsequent periods, available estimates under-report impacts to a large extent. A comprehensive understanding and

estimation of both direct and indirect impacts of disasters is vital to better design, prepare, adapt, and build back better.

2. Role of technologies in building climate-resilient infrastructure

While estimating financial needs and identifying sources of mobilizing funds for the same forms one aspect, another related issue is identifying areas where the finances will be spent. In order to 'build back better', it is critical to focus on resilient infrastructure that is able to withstand similar disaster occurrences in the future. This is particularly true for regions that experience disasters or disaster-like situations rather frequently or seasonally due to the locational factor.

According to estimates by Fay et al. (2019), low and middle-income countries invest approximately 3.4 to 5% of their Gross Domestic Product (GDP) on infrastructure each year. However, the quality of infrastructure services provided exhibits significant variation across countries. Added to this is the complexity brought on by disasters. Hallegatte et al. (2019), who examine the resilience of infrastructure systems, i.e., power, transport, and water & sanitation, find that designs for resilient assets in low and middle-income countries are likely to result in incremental costs of 3%, beyond the overall investment needs (or less than 0.1% of their GDP). This, of course, is with the caveat that the necessary data, risk models, etc., are already available so that efforts are directed toward only those regions and assets that are more exposed to disasters. Bereft of this information, the study found that improving the resiliency of infrastructural assets is likely to be ten times more expensive. Future climate resilient infrastructure thus needs to be cost-effective and tolerant to increasing climate-related disaster risks, with the design, construction as well as the management of the same to be advanced and modernised.

Traditional solutions for improving resiliency may include utilizing alternative materials, constructing deeper foundations for assets, flood protection structures to prevent inundation, elevating the height of assets, increasing capacity of culverts to handle higher precipitation levels, using pavement mixtures that can withstand high temperatures, constructing ripraps and dikes, installation of impact resistant glass in buildings, installation of emergency power backups, and so on (Hallegatte et al. (2019); Swanson et al. (2021)). Such foresight is required in

redevelopment plans in order to be better equipped to manage disasters and to accordingly apportion necessary funds to reach the desired outcomes.

In this process, technologies can play a crucial role in building climate-resilient infrastructure.

The integration of technologies in disaster management, particularly in development of climate resilient infrastructure provides several benefits. Technologies can facilitate automated and efficient assessments to ensure adaptive management of infrastructure systems, leading to reduction of operational and maintenance costs through predictive maintenance strategies. Further, technological solutions expedite the establishment of interconnections and interdependencies to help in the integration of nature-based solutions. In addition, the relatively more accurate and automated decision-making helps to strike the balance between efficiency and resilience of infrastructure, in turn to ensure safer infrastructure systems (Lu and Polycarp, 2023). Thus, digital solutions like internet of things (IoT), artificial intelligence (AI), building information modelling (BIM), digital twins (DT), and agent-based modelling (ABM), through means of data collection, processing, and communication, as well as generation of actionable intelligence like early warning systems, have immense potential to elevate climate resilience of infrastructure.

While the potential remains vast, the availability of such technologies remains limited, specifically for emerging markets. The initial access to finance for technology developers is difficult to source and severely restricted. These technological solutions can aid in reducing disaster-related losses, help generate greater revenues, as well as save lives and livelihoods. Thus, the need is to put in place policy frameworks that acknowledge and promote the use of such technologies to attract private investments, as well as provide public financial support for the early development phase to encourage greater innovation and deployment of such digital solutions.

6. Conclusion

The paper used the ICRIER *Prakriti* Disaster Management Model, to study the impact of disasters on local businesses and the economy. It assessed the impact of floods and cyclones in Assam and Andhra Pradesh respectively using information on

direct damages from disaster incidences. The paper estimated annual production losses from the model and used it to compute its impact on the GSVA and employment.

The modelling exercise highlighted that even though the states differ in terms of the direct impact experienced on account of the disasters (with Andhra Pradesh being affected twice as much), the indirect impacts were found to be manifold. Thus, studying the transmission mechanisms of disaster impact and welfare-inducing strategies for redevelopment post-disaster is essential. The paper also highlighted the need for uniform standards to report damage/loss numbers across states to make claims for relief measures or to make loss and damage finance less cumbersome to assess. Finally, it also delved into the role of technology in building infrastructure that can withstand the effects of climate-induced disasters. Policy structures are required that recognize and encourage the adoption of relevant technologies as well as attract necessary investments.

Based on the modelling analysis, the impact of disasters on the production capabilities of Andhra Pradesh and Assam differed significantly. In case of the former, cyclones caused a substantial loss of 1.53% in production value (INR 23,18,220 lakh) in 2018-19, with the potential for even greater losses in the future due to increasing cyclone intensity and frequency driven by climate change. On the other hand, Assam, experienced direct losses to the tune of INR 68,488 lakh, when accounting for public and private sector asset losses. The specific sectors affected also varied between the two states, with Andhra Pradesh's chemical sector hit hardest and Assam experiencing adverse effects in water supply, rubber and plastics, and textiles.

When translating the loss in production capacity into a reduction in intermediate consumption, a similar pattern emerged, albeit with varying degrees of impact. Assam saw a reduction of 0.18% in total intermediate consumption, amounting to INR 56,754 lakh. In contrast, Andhra Pradesh experienced a much higher reduction of 2.91% in total intermediate consumption, equivalent to INR 20,77,912 lakh. This reduction mirrored the sectoral patterns observed for production losses. Furthermore, while there was a notable difference in value-added impacts between the two states, the gap considerably narrowed when assessing employment impacts.

It is important to emphasize that the extreme reactions seen in the model are uncommon in typical situations. Usually, when there is a shortage of inputs, the response involves importing resources from different regions, be it within the state, country, or globally, and sometimes implementing rationing measures to control production, demand, and prices. Future iterations of the model will incorporate these rational decision-making elements to improve upon the model outputs. Looking at these direct and indirect impacts of disasters would be especially useful for India to access loss and damage funds. In fact, the recent decisions at COP28 related to

“operationalization of the new funding arrangements, including a fund, for responding to loss and damage referred to in paragraphs 2-3 of decisions 2/CP.27 and 2/CMA.4” also advocate for assisting developing countries particularly vulnerable to adverse effects of climate change. Additionally, the model underscores that even when facing similar climate-induced disasters, states can experience vastly different impacts due to their unique resilience mechanisms, developmental stages, governance models, and other factors. Future versions of the model will delve into exploring and understanding these variations.

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Annexure

Annexure 1

Table A. 1: Disaster Subgroup, Type and Subtype

Disaster Subgroup	Disaster Type	Disaster Subtype
Climatological	Droughts	Droughts
	Glacial-lake outbursts	Glacial-lake outbursts
	Wildfires	Forest fire and land fire (brush, bush and pasture)
Hydrological	Floods	Coastal flood, flash flood and riverine flood
	Landslides	Landslide, avalanche, mudslide and rockfall
Meteorological	Extreme Temperatures	Heat wave, cold wave, extreme weather conditions
	Storms	Convection storm, extra tropical storm, tropical cyclone

Source: Goldar et al. (2023)

Table A. 2: Region and instance selection

Country	Disaster	Frequency in country during 1990-2022	State/Province of Focus	Frequency in State/Province of focus during 1990-2022	Year with highest frequency at national level (total occurrences in that year) ⁹	Frequency in State/Province of focus in selected year
India	Storms	117	Andhra Pradesh	34	2018 (11)	3
	Floods	231	Assam	57	2015 (10)	4

Source: Authors' construction using EMDAT (2022)

Table A.3: Financial Assistance sought from the Central Government

S No.	Item	Amount (in ₹ Crores)
1.	Gratuitous Relief	51.62
(a)	Food Provisioning	41.03
(b)	Providing temporary accommodation	7.04
(c)	Providing compensation to next of kin	2.64
(d)	Additional medicines and vaccines	0.91
2.	Conducting search and rescue operations/relief measures (transportation of materials, man, medical care)	7.15
3.	Agricultural sector: providing assistance to small and marginal farmers (for crop damage, desilting, removing debris from agricultural land, covering losses incurred due to landslides)	284.82
4.	Animal Husbandry: Replacement of animals	1.57
(a)	Milch animals (Buffalo/ Cow/ Camel)	0.61
(b)	Sheep/ Goat	0.64
(c)	Draught Animal (Camel/Horse/ Bullock)	0.14
(d)	Calf/Donkey/ Pony/Pig	0.13
(e)	Poultry/Birds	0.05

9 Between 2010-2022

5.	Housing (construction & repair)	72.88
(a)	Construction of fully and severely damaged pucca & kutcha houses	54.39
(b)	Repair of partially damaged pucca & kutcha houses and huts	18.49
6.	Restoration of damaged infrastructure	1105.75
(a)	Water Resources Department (embankment breaches and damages to other structures such as sluice gates, culverts etc.)	616.65
(b)	Irrigation (Restoration & repair of damaged canals, structures etc.)	45.7
(c)	Social Welfare Department (Repair of fully and partially damaged <i>anganwadi</i> centres)	67.10
(d)	Public Works Department (restoration of damaged roads, bridges etc.)	200
(e)	Repair of damaged veterinary sub centres	0.17
(f)	Repair of drinking water sources	7.14
(g)	Primary education (repair of damages to school buildings)	37.95
(h)	Repair of damaged health centres	2.04
(i)	Urban flood damage under Guwahati Municipal Corporation	129
Grand Total (1+2+3+4+5+6)		1523.79

Source: Adapted from Flood Memorandum Report (2015), Government of Assam

Table A. 4: State Government of Andhra Pradesh: Financial relief measures for cyclone *Titli*

State Government measures for relief	Amount (in ₹)
Relief in case of death due to the cyclone (per life)	5 lakhs
Compensation (per hectare):	
Banana	30,000
Cashew	25,000
Agricultural crops	20,000
Assistance for replantation for small and marginal farmer (per hectare)	40,000
Compensation for death and permanent disability of milch cattle (per animal)	30000
Compensation for death of goats and sheeps (per animal)	3,000

Source: Authors' compilation; UNDP (n.d). Note on Severe Cyclone Storm *Titli's* Impact on the State of Andhra Pradesh & Strengthening Local Governance System for Mainstreaming DRR and CCA [GOI-UNDP Rehabilitation Initiatives].

Annexure II

RIO construction

The present paper follows a similar framework like the REGEMI model (Regional Environmental General Equilibrium Model for India; Bussolo et al., 2003) and studies the regional effects of a shock like a disaster and the finance required to build its adaptive capacity. A disaster occurring in a particular state does not only alter that state's own macroeconomic factors like output, household and industrial consumption, value added, and employment structure, but also affects the value added, production, consumption, employment, and the net export and import of other states. Thus, regional analysis is the key to best determine both, the direct and the spill-over effects of a disaster. The national IO serves as a benchmark model for the estimation of some of the regional components. The construction of a RIO table

entails the estimation of regional final demand and supply, regional intermediate consumption, regional household savings, and regional direct tax payments and subsidies. Therefore, the present paper adds to the literature by constructing two regional (State) IO tables with the help of national coefficients as provided in the India IO table in Chaudhuri, Pratap, & Pohit (2024).

Chaudhuri, Pratap, & Pohit (2024), provide an IO table for the base year 2018-19 using the National Supply Use Table (SUT) provided by the Ministry of Statistics and Programme Implementation (MoSPI), Government of India. They provide a symmetric 65-sector IO. However, for the purposes of the current study, these sectors were aggregated to a lesser number of 37 sectors for creation of two RIO tables for the state of Assam and Andhra Pradesh. The key data requirement for input-output tables were – sectoral value of output, inputs consumed,

value addition by each sector, and final demand consumption by households, governments, rest of the country and the rest of the world. The RIO tables are estimated at purchaser's price.

Concordances between the selected 37 sectors (see Annexure III) and the National Industries Classification (NIC) codes-2008 and the National Product Classification For Manufacturing Sector (NPCMS) codes-2011 was developed to facilitate mapping of values across different variables and datasets.

The details of the methodology for the estimation of the regional components to prepare the RIO tables are as provided below.

Output Structure

Primary Sector: Crops, Livestock, Forestry & Logging, Fishing & Aquaculture and Mining and Quarrying (M&Q)

The estimates for GSVA for Assam and Andhra Pradesh, for the aforementioned primary sectors for 2018-19 were obtained from MoSPI. With specific reference to the M&Q sector, since the state level GSVA data does not provide a bifurcation between the subcomponents of mining of (a) coal & lignite, (b) petroleum & natural gas and (c) iron ore, (d) non-ferrous metal ores and (e) other mining, national level ratios were used to arrive at the same. Similarly, data pertaining to the state-wise Gross Value of Output (GVO) for the sub-sectors for the states in question, was calculated using the national level ratios of GVA/GVO, obtained from the all-India *Supply and Use Table*.

Secondary Sector: Food and Beverages, Textile and Apparel, Leather, Basic Metals and Metal Products, Electric and Electronic Equipment, Machinery and Equipment, Transport Equipment, Coke and Refined Petroleum Products, Chemical and Chemical Products, Pharmaceuticals, Rubber and Plastic Products, Non-metallic Mineral Products, Wood Products, Paper and Printing, and Other Manufacturing

Similar to the primary sectors, the estimates for GSVA for Assam and Andhra Pradesh, were obtained from MoSPI. However, they were aggregated under the heading 'manufacturing'. The value-added figure was disaggregated into the aforementioned secondary

sectors using information from Annual Survey of Industries (ASI). Relative shares were computed using ASI value added totals for each sector and were then multiplied with the 'manufacturing' value added figure from MoSPI. State-wise GVO for the secondary sectors for both states was calculated using the national level ratios of GVA/GVO, obtained from the all-India *Supply and Use Table*.

Service Sector: Construction, Electricity, Gas, Water Supply, transport services, storage and warehousing, communication, trade, hotel and restaurants, financial services, real estate and professional services, other services and public administration and defence

The estimates for GSVA for Assam and Andhra Pradesh, for the aforementioned service sectors for 2018-19 were obtained from the MoSPI. With specific reference to the Electricity, Gas, and Water Supply sectors, the state level GSVA data does not provide a bifurcation between these sub-components. It provides a single value for all three, clubbed into one. Therefore, national level ratios were used to arrive at the numbers for the three sub-components. Similarly, data pertaining to the state-wise GVO for the sub-sectors for the states in question was calculated using the national level ratios of GVA/GVO, obtained from the all-India *Supply and Use Table*.

Input Structure

Primary Sector: Crops, Livestock, Forestry & Logging, Fishing & Aquaculture and Mining and Quarrying (M&Q)

Secondary Sector: Food and Beverages, Textile and Apparel, Leather, Basic Metals and Metal Products, Electric and Electronic Equipment, Machinery and Equipment, Transport Equipment, Coke and Refined Petroleum Products, Chemical and Chemical Products, Pharmaceuticals, Rubber and Plastic Products, Non-metallic Mineral Products, Wood Products, Paper and Printing, and Other Manufacturing

Service Sector: Construction, Electricity, Gas, Water Supply, transport services, storage and warehousing, communication, trade, hotel and restaurants, financial services, real estate and professional services, other services and public administration and defence

The value of inputs was calculated by subtracting GVA from GVO and the input structure that was

used followed the same proportions as adopted by Chaudhuri, Pratap, & Pohit (2024), for the all India IO for 2018-19.

Final Demand

Gross Fixed Capital Formation (GFCF)

The data for GFCF for the states in question was obtained from the *Handbook of Statistics on Indian States* published by the Reserve Bank of India. The estimates so found were then distributed across sectors in the same proportion as adopted by Chaudhuri, Pratap, & Pohit (2024).

Government Final Consumption Expenditure (GFCE)

Estimates of GFCE were not available for the two states in question. Therefore, the ratio of sum of GFCE to sum of GSDP for the states of Uttarakhand, Maharashtra, Karnataka, Chhattisgarh, Himachal Pradesh, Haryana, Madhya Pradesh, Tripura, Rajasthan and Punjab was calculated¹⁰ and used to arrive at the respective figures for Assam and Andhra Pradesh.

Private Final Consumption Expenditure (PFCE)

For the calculation of item-wise PFCE, data from National Sample Survey Office (NSSO) 68th Round Household Consumption Expenditure Survey (2011-12) has been used. As a first step in the process, a concordance was developed between the selected 37 sectors and the items of consumption in the NSS consumer expenditure survey. Each item code pertaining to diverse consumer categories in various blocks of the 68th NSS consumer expenditure survey was mapped with the 37 sectors of the SAM. The previously developed concordance between the 37 sectors and the NIC codes under the study was further utilised to aid the classification of consumer items as

well as to clear any discrepancies in the classification hence developed. The state totals have been used to calculate relative shares and distribute the figures for PFCE computed by Chaudhuri, Pratap, & Pohit (2024).

Taxes

The data for tax revenue collected by Assam and Andhra Pradesh was sourced from the *State Finances Audit Report of the Controller and Auditor General of India (2022)* and the *Annual Financial Statement and Explanatory Memorandum on Budget 2020-21* respectively. The data so obtained was further bifurcated into direct and indirect taxes.

Subsidies

The data for subsidies provided by Assam and Andhra Pradesh was collated from the *State Finances Audit Report of the Controller and Auditor General of India 2022* of the two states.

Disaster induced infrastructure damages

Expenditure incurred by the government for post-disaster repair/restoration of infrastructure has been used as a proxy for the monetary value of damages induced by floods and storms in Assam and Andhra Pradesh, respectively. The data for the same was collated via extensive review of grey literature and other secondary sources. The figures so obtained were subsequently concorded with the relevant sectors in the IO model. For instance, expenditure incurred on providing medical and health services has been included as a negative entry against the *Real estate, ownership of dwelling & professional services* sector. Similarly, costs of repairing damage to drinking water sources etc. have been recorded against the *Water Supply* sector. Details of this concordance exercise has been provided in Table A.6 below.

¹⁰ 4.52 % of GSDP

Table A. 5: Concordance of expenditure head with IO sector

Category of Expenditure	IO sector concordance
Providing assistance to small and marginal farmers (for crop damage, desilting, removing debris from agricultural land, covering losses incurred due to landslides)	Agriculture
Horticulture	
Housing (construction & repair)	Construction
Restoration and reconstruction of power sector	Electricity
Restoration of fisheries	Fishing & Aquaculture
Animal Husbandry (replacement of animals)	Livestock & Livestock Products
Restoration of handlooms and textiles sector	Manufacturing of Textile and Apparel
Repair of fully and partially damaged <i>anganwadi</i> centres	Other Services
Repair of damaged veterinary sub-centres	
Repair of river guard wall, damage to roads, bridges, drains etc.	
Panchayat Raj	
Municipal Administration & Sanitation	Real estate, ownership of dwelling & professional services
Repair of damages to school buildings	
Repair of damaged health centres	Water supply
Repair of embankment breaches and damages to other structures such as sluice gates, culverts etc.	
Restoration & repair of damaged canals, structures etc.	
Repair and restoration of water resources	

Source: Authors' construction

Net Exports (Rest of the World and Rest of India)

The data for net exports of goods has been computed using data from state-wise principal exports and imports available on web-based platform, India Stats. The exported and imported commodities as found in the state trade data were concorded with the NPCMS codes-2011. It facilitated the mapping exercise of trade data with the 37 sectors, utilising the previously developed concordance between the sectors and the NPCMS codes. The products thus concorded were then aggregated as per the 37 sectors, mentioned in Annexure III. The data for net exports of services has been computed using the Prowess database and the India IO table from Chaudhuri, Pratap, & Pohit (2024). It is constructed using state-wise and product-wise shares of exports and imports of companies in the service sector available in Prowess data. The state export and import proportions in all-India are then estimated for Andhra Pradesh and Assam and then

multiplied with product-wise export and import data of services provided in the India IO table. Net exports are derived as the difference between exports and imports. If the value of net exports is negative, this implies that the state is a net importer, and if it is positive, the state is a net exporter.

The present paper does not separately compute inter-state goods and services movement because of the unavailability of reliable data. Directorate General of Commercial Intelligence and Statistics (DGCI&S) provides data on state-wise and product-wise movement of few goods (not services), that too only by road. There are many caveats of using this data and will be attempted to be incorporated in subsequent iterations (following Saluja, 2014). For the present analysis' purpose, the difference between production values and demand totals have been taken to represent inter-state trade of goods and services.

Annexure III

List of 37 sectors being used in the input-output table for 2018-19

S No.	Sectors
1	Agriculture
2	Livestock & Livestock Products
3	Forestry and Logging
4	Fishing & Aquaculture
5	Mining of Coal & Lignite
6	Mining of Petroleum and Natural Gas
7	Mining of Iron Ore
8	Mining of Non-ferrous metal ores
9	Other Mining
10	Manufacturing of Food and Beverages
11	Manufacturing of Textile and Apparel
12	Manufacturing of leather and related products
13	Manufacturing of Basic metals and metal products
14	Manufacturing of Electric and Electronic Equipment
15	Manufacturing of machinery and equipment n.e.c.
16	Manufacturing of Transport
17	Manufacturing of coke and refined petroleum products
18	Manufacturing of chemical and chemical products except pharmaceuticals, medicinal and botanical products
19	Manufacturing of pharmaceutical; medicinal chemicals and botanical products
20	Manufacturing of rubber & plastic products
21	Manufacturing of other non-metallic mineral products
23	Manufacturing of Wood Products
22	Paper And Printing
24	Other Manufacturing
25	Construction
26	Electricity
27	Gas
28	Water supply
29	Transport services
30	Storage & warehousing
31	Communication
32	Trade
33	Hotels & Restaurant
34	Financial services
35	Real estate, ownership of dwelling & professional services
36	Other Services
37	Public administration & defence

Annexure IV: Disaster Impacts (values in INR lakhs)

	Sectors	Life of asset (buildings and machineries)	Life span (years)	Andhra Pradesh				Assam			
				Private Cyclone Damage	Public Cyclone Damage	Annualised Value	Production Losses	Private Flood Damage	Public Flood Damage	Annualised Value	Production Losses
1	Agriculture	Buildings	70		-149855	-9146.1	-32664.7		-28482	-1738.3	-10864.7
	Agriculture	Machineries	25								
2	Livestock	Buildings	20		-3862	-336.7	-1202.5		-157	-13.7	-85.5
	Livestock	Machineries	0								
3	Forestry and Logging	Buildings	70								
	Forestry and Logging	Machineries	25								
4	Fishing & Aquaculture	Buildings	70		-5355	-326.8	-1167.3				
	Fishing & Aquaculture	Machineries	25								
5	Coal & Lignite	Buildings	41								
	Coal & Lignite	Machineries	25								
6	Mining of Petroleum and Natural Gas	Buildings	30								
	Mining of Petroleum and Natural Gas	Machineries	25								
7	Iron Ore	Buildings	70								
	Iron Ore	Machineries	15								
8	Non-ferrous metal ores	Buildings	70								
	Non-ferrous metal ores	Machineries	15								
9	Other Mining	Buildings	70								
	Other Mining	Machineries	15								
10	Food and Beverages	Buildings	70								
	Food and Beverages	Machineries	25								
11	Textile and Apparel	Buildings	70		-8	-0.5	-1.7	-384.8		-23.5	-146.8
	Textile and Apparel	Machineries	10					-502.7		-68.3	-426.9
12	Manufacture of leather and related products	Buildings	70								
	Manufacture of leather and related products	Machineries	10								
13	Basic metals and metal products	Buildings	70	-53478.3		-3263.9	-11657.0				
	Basic metals and metal products	Machineries	10								
14	Electric and Electronic Equipment	Buildings	70					-1511.5		-92.3	-576.6
	Electric and Electronic Equipment	Machineries	10					-976.2		-132.6	-829.0
15	Manufacture of machinery and equipments n.e.c.	Buildings	70								
	Manufacture of machinery and equipments n.e.c.	Machineries	26								
16	Manufacture of Transport	Buildings	26					-16.5		-1.3	-7.9
	Manufacture of Transport	Machineries	6					-0.7		-0.1	-0.9
17	Manufacture of coke and refined petroleum products	Buildings	70	-1720.3		-105.0	-375.0				
	Manufacture of coke and refined petroleum products	Machineries	25								
18	Manufacture of chemical and chemical products except pharmaceuticals, medicinal and botanical products	Buildings	70	-61607.6		-3760.1	-13428.9				
	Manufacture of chemical and chemical products except pharmaceuticals, medicinal and botanical products	Machineries	10	-4505819.9		-612196.6	-2186416.3				
19	Manufacture of pharmaceutical; medicinal chemicals and botanical products	Buildings	70								
	Manufacture of pharmaceutical; medicinal chemicals and botanical products	Machineries	10								

20	Manufacture of rubber & plastic products	Buildings	70	-23393.2		-1427.8	-5099.1	-7885.6		-481.3	-3008.0	
	Manufacture of rubber & plastic products	Machineries	10	-3323.6		-451.6	-1612.7	-8072.5		-1096.8	-6855.0	
21	Manufacture of other non-metallic mineral products	Buildings	70									
	Manufacture of other non-metallic mineral products	Machineries	10									
22	Wood Products	Buildings	70	-1960.9		-119.7	-427.4	-585.3		-35.7	-223.3	
	Wood Products	Machineries	15	-1051.9		-108.3	-386.8	-782.9		-80.6	-503.8	
23	Paper And Printing	Buildings	70	-11628.0		-709.7	-2534.6					
	Paper And Printing	Machineries	15	-44662.0		-4598.5	-16423.3					
24	Other Manufacturing	Buildings	70									
	Other Manufacturing	Machineries	10	-7478.6		-1016.1	-3628.9					
25	Construction	Buildings	70		-44815	-2735.2	-9768.6		-7288	-444.8	-2780.1	
	Construction	Machineries	25									
26	Electricity	Buildings	70		-50596	-3088.0	-11028.7					
	Electricity	Machineries	15									
27	Gas	Buildings	70									
	Gas	Machineries	15									
28	Water supply	Buildings	70		-23462	-1432.0	-5114.1		-66949	-4086.1	-25538.2	
	Water supply	Machineries	10									
29	Transport services	Buildings	70									
	Transport services	Machineries	10									
30	Storage & warehousing	Buildings	70									
	Storage & warehousing	Machineries	25									
31	Communication	Buildings	70									
	Communication	Machineries	10									
32	Trade	Buildings	70									
	Trade	Machineries	10									
33	Hotels & Restaurant	Buildings	70									
	Hotels & Restaurant	Machineries	10									
34	Financial services	Buildings	70									
	Financial services	Machineries	10									
35	Real estate, ownership of dwelling & professional services	Buildings	70		-75	-4.6	-16.3		-3999	-244.1	-1525.4	
	Real estate, ownership of dwelling & professional services	Machineries	10									
36	Other Services	Buildings	70		-70035	-4274.5	-15265.9		-39627	-2418.6	-15116.0	
	Other Services	Machineries	10									
37	Public administration. & defence	Buildings	70									
	Public administration. & defence	Machineries	10									
	Total					-348063	-649102	-2318220		-146502	-10958	-68488

Source: Authors' construction using data obtained from Annual Survey of Industries (ASI), government sources and other literature;

Note: Capital-Output Ratio for Andhra Pradesh and Assam taken as: 0.28 and 0.16

Annexure V: Reductions in Production and Intermediate Consumption in Assam and Andhra Pradesh (INR Lakhs)

Sector	Assam					Andhra Pradesh				
	Production Losses		Reduction in Intermediate Consumption			Production Losses		Reduction in Intermediate Consumption		
	Total Production	Losses	Pre-disaster	Post-disaster	Reductions	Total Production	Losses	Pre-disaster	Post-disaster	Reductions
Agriculture	4602767.7	-10864.7	1540852.7	1537215.6	-3637.1	13600294.8	-32664.7	5742979.7	5729186.4	-13793.3
Livestock	456908.1	-85.5	565751.0	565645.1	-105.9	11945280.1	-1202.5	2024481.7	2024277.9	-203.8
Forestry and Logging	370046.6		282464.6	282464.6	0.0	946987.7		976508.5	976508.5	0.0
Fishing & Aquaculture	810426.9		92956.5	92956.5	0.0	7973390.9	-326.8	338766.7	338752.8	-13.9
Coal & Lignite	1341288.7		469485.0	469485.0	0.0	919714.0		1575843.4	1575843.4	0.0
Mining of Petroleum and Natural Gas	1481907.9		8843703.9	8843703.9	0.0	1016135.8		2993796.4	2993796.4	0.0
Iron Ore	801322.7		29091.5	29091.5	0.0	549462.4		372544.4	372544.4	0.0
Non-ferrous metal ores	538546.9		36532.8	36532.8	0.0	369278.5		290582.3	290582.3	0.0
Other Mining	1593737.1		326573.1	326573.1	0.0	1092816.5		888495.8	888495.8	0.0
Food and Beverages	4016762.7		998527.0	998527.0	0.0	10737299.5		2958736.2	2958736.2	0.0
Textile and Apparel	51793.9	-573.7	168512.3	166645.8	-1866.5	1789343.1	-1.7	740070.4	740069.6	-0.7
Manufacture of leather and related products			4846.9	4846.9	0.0	158822.7		34273.2	34273.2	0.0
Basic metals and metal products	553983.4		1241672.4	1241672.4	0.0	7797011.5	-11657.0	5422734.8	5414627.5	-8107.3
Electric and Electronic Equipment	506488.3	-1405.6	350142.8	349171.1	-971.7	2013910.2		1059195.8	1059195.8	0.0
Manufacture of machinery and equipments n.e.c.	16732.7		303032.0	303032.0	0.0	430868.0		916689.7	916689.7	0.0
Manufacture of Transport	4320.2	-8.8	336920.7	336230.8	-689.9	477500.0		1009699.0	1009699.0	0.0
Manufacture of coke and refined petroleum products	11393678.3		1258904.8	1258904.8	0.0	3236243.3	-375.0	3403504.9	3403110.5	-394.4
Manufacture of chemical and chemical products except pharmaceuticals, medicinal and botanical products	2065616.6		1473283.6	1473283.6	0.0	3399938.6	-2199845.2	2948956.3	1040907.9	-1908048.4
Manufacture of pharmaceutical; medicinal chemicals and botanical products	616206.0		195167.1	195167.1	0.0	2644045.5		798458.7	798458.7	0.0
Manufacture of rubber & plastic products	325366.3	-9863.0	511545.2	496038.5	-15506.7	340296.9	-6711.9	1528041.2	1497902.7	-30138.5
Manufacture of other non-metallic mineral products	973272.2		710504.4	710504.4	0.0	2999942.8		1997986.4	1997986.4	0.0
Wood Products	88324.4	-727.1	270930.9	268700.6	-2230.3	71701.8	-814.2	671782.5	664154.0	-7628.5
Paper And Printing	303751.5		257075.4	257075.4	0.0	635071.3	-18957.9	654529.1	634990.3	-19538.8
Other Manufacturing	879.5		833533.0	833533.0	0.0	118900.5	-3628.9	2380676.5	2380816.2	-72660.2
Construction	5748697.3	-2780.1	1157406.6	1156846.9	-559.7	16494842.4	-9768.6	3176643.5	3174762.2	-1881.3
Electricity	1366019.9		996635.0	996635.0	0.0	3901638.4	-11028.7	3052523.6	3043895.1	-8628.5
Gas	191200.4		91659.2	91659.2	0.0	546108.2		209347.9	209347.9	0.0
Water supply	174757.3	-25538.2	191929.4	163881.8	-28047.6	499143.3	-5114.1	475408.1	470537.1	-4871.0
Transport services	2574154.8		1517735.0	1517735.0	0.0	13259461.9		3493569.4	3493569.4	0.0
Storage & warehousing	36839.5		55217.4	55217.4	0.0	103651.7		111277.1	111277.1	0.0
Communication	1286425.8		647520.4	647520.4	0.0	3286453.1		2198802.2	2198802.2	0.0
Trade	5598148.4		2498964.2	2498964.2	0.0	7100828.8		6573735.0	6573735.0	0.0
Hotels & Restaurant	452117.7		226360.7	226360.7	0.0	2765235.6		654394.9	654394.9	0.0
Financial services	1219240.7		1230196.9	1230196.9	0.0	4641777.2		3350265.4	3350265.4	0.0
Real estate, ownership of dwelling & professional services	2173417.1	-1525.4	1914011.3	1912668.0	-1343.4	9002653.9	-16.3	4936244.7	4936235.8	-9.0
Other Services	4522719.3	-15116.0	537332.1	535536.2	-1795.9	10413584.3	-15265.9	1360696.9	1358702.1	-1994.7
Public administration. & defence	2123911.0		0.0	0.0	0.0	3860166.6		0.0	0.0	0.0
Total	60381777.7	-68488.1	32166977.8	32110222.9	-56754.8	151139801.6	-2317379.6	71322241.8	69244329.6	-2077912.2

Source: Authors' computation

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