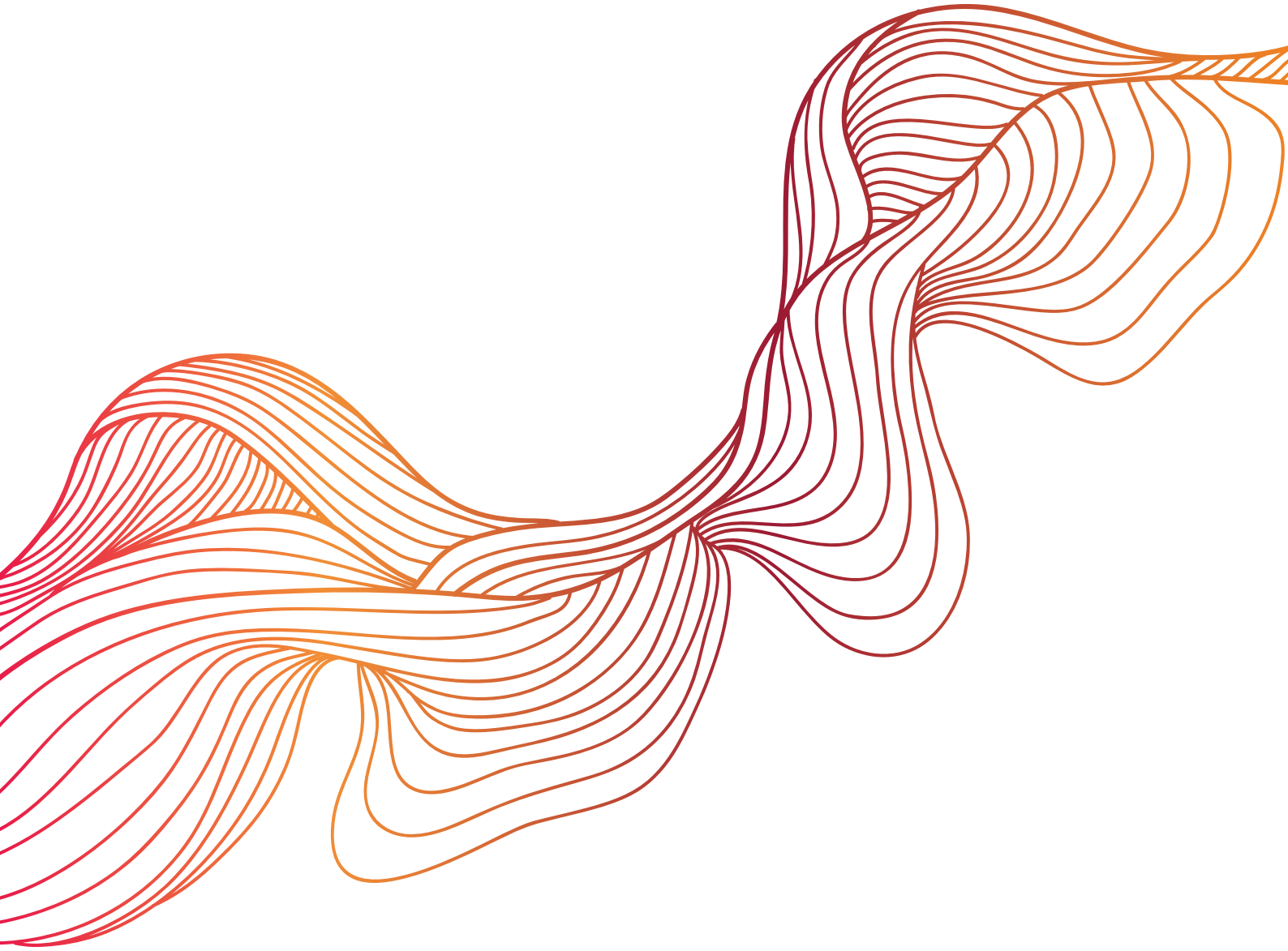
El Niño Storylines and Plausible Climate Futures for the Indo-Pacific

East India Case Report



Red Cross Red Crescent Climate Centre

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Climate Centre

This document is part of a larger research project conducted by the Red Cross Red Crescent Climate Centre (Climate Centre) for the United Kingdom's Foreign Commonwealth and Development Office (FCDO) exploring plausible future El Niño impacts. Nothing herein constitutes the views of FCDO. The document employs a storylines methodology, an innovative evidence-based approach to climatologically represent various scenarios that may emerge given these uncertainties in future projections. The research examines the potential impacts of the El Niño Southern Oscillation (ENSO) which could be experienced in the Indo-Pacific region across a) the next 2-10 years (near term) and b) under the scenario in which global land temperatures exceed 2ºC since the industrial revolution. This case report focuses on East India and is one of three case reports (Lower Mekong Basin and the Central Dry Zone, Myanmar) that comprise this project.

For more information on the findings of the project please see the summary report highlighting the findings across the regions, the methodology employed, and key recommendations.

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Executive summary

This report investigates the potential impacts of El Niño Southern Oscillation and the Indian Ocean Dipole (IOD) in East India over the near term (next 2–10 years) and longer term (with 2°C of global temperature increase since pre-industrial levels) might have on the region. To do this, plausible climatological storylines were developed and analysed according to four typologies (health, trade, mobility, and security) using a retrospective analysis approach.

The following two storylines were developed:

EAST INDIA (WEST BENGAL, ODISHA, JHARKHAND AND BIHAR)

Storyline 1: Near term (2-10 years)		**Storyline 2: 2°C global warming**
Following a La Niña phase, which will likely last two to three years, a transition to an El Niño Pacific event is likely to occur. A positive IOD phase in the Indian Ocean could also be simultaneously triggered. This storyline has two subsections:		
Sub storyline 1 A: If the effects of the positive IOD are more dominant than the El Niño, **increased high temperatures will persist throughout the seasons**, combined with a delayed monsoon which is **wetter than normal**. Once the monsoon arrives, there is also a likelihood **of increased precipitation** and **flooding** during the **wetter monsoon season**.	Sub storyline 1 B: If the effect of **El Niño is more dominant than the IOD, increased high temperatures** will persist throughout the seasons, combined with a delayed monsoon which is **drier than normal**.	Under a 2°C warmer world the **Indian monsoon rainfall will likely increase**. However, we also anticipate ongoing El Niño and La Niña variability and **increased magnitude rainfall and temperature responses to El Niño and La Niña**.

Storyline key impacts

It is important to note, this work was conducted as a first stage desk-based research project, limited in scope to applying the methodology for the following key sectoral areas of health, trade, mobility and security. For future iterations, it would be possible to explore alternative or further sectoral impacts.

Health impacts ranged from differentiated nutritional impacts especially among children and babies, increases in water and vector-borne diseases, heat-related illnesses and mental health challenges.

Trade impacts include damaged infrastructure which could inhibit access to markets; decreased agricultural production; decreased yields leading to decreased exports; impacts on workforce as a result of increasing extreme heat; increased likelihood of blackouts and disrupted commerce; impacts on communities relying on forest ecosystems for non-timber forest products.

Mobility impacts centre around increased short term and protracted displacement; the destruction of infrastructure resulting in people becoming trapped and immobile with limited access to resources or means of communication; increased cross-border migration from neighbouring countries; increased migration as a form of livelihood diversification or adaptation; increased rate of migration amongst people from a marginalised lower caste; increased duration of seasonal migration; climate-induced displacement and the potential threat of migration journeys becoming more dangerous.

Security impacts focus on the ways in which human security implications create a backdrop for understanding security consequences related to violence and conflict. Assessed under this framing are tensions around border management, elements of personal security and human trafficking and the role of decreased health, economic and water security.

The report provides several **recommended adaptation intervention** points based on the outlined impacts under each storyline. These are presented across different durations and varying windows of opportunity, ranging from long term disaster risk reduction (DRR) and adaptation, anticipatory action, disaster response, and disaster recovery.

In conclusion the report provides five recommendations going forward :

1. Prepare for a future with persistent oscillation between La Niña and El Niño and both positive and negative IOD events, in an increasingly warmer world with more intense precipitation.
2. Monitor climatological conditions at local, national, regional, and international levels to design and implement informed action.
3. Conduct targeted research and analysis to close key knowledge gaps that currently limit evidence-based policy decisions.
4. Recognise and embrace the role of understanding and working within complexity when addressing future climate challenges.
5. Use the storylines as a discussion tool for preparedness measures within countries and regions.

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Introduction

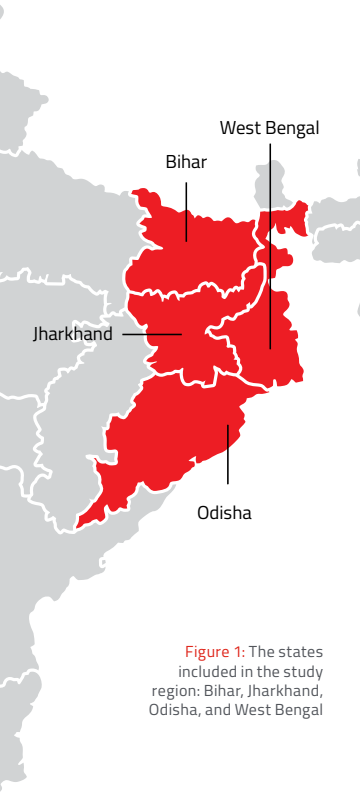


Figure 1: The states included in the study region: Bihar, Jharkhand, Odisha, and West Bengal

The eastern states of India – Bihar, Jharkhand, Odisha, and West Bengal – are home to 22 per cent of the country's population. Much of the population in these states lives in rural areas and depends on agriculture-related activities for their livelihoods. Despite abundant water and fertile soil, agriculture remains subsistence-level. The geographical location of these states on the east coast of India and their climatic conditions mean that they have historically been highly vulnerable to the effects of multiple climate-related hazards; mainly cyclones, droughts, heatwaves and floods. Climate change exacerbates existing vulnerabilities and disproportionately affects marginalised groups in these states where adaptation, poverty reduction, and inclusive development are critical to levels of resilience and sustainable progress.

Overview of storylines

Overview of storyline objectives and methodology

The storyline methodology used in this research was developed by the Red Cross Red Crescent Climate Centre (Climate Centre) and builds on academic research in the areas of climate storylines and forensic investigations of disasters e.g. Jack et al.,(2020), Van den Hurk et al.,(2023). **The storyline approach combines elements of interdisciplinary methodological approaches to develop a robust and innovative way to understanding risk complexity in a changing climate.** Using an integrated approach, the methodology offers novelty by way of combining varying aspects of human security as a pathway to understand the risks related to climate change and climate security.

Climate projections refer to the future scientific estimates of climate conditions. They are based on climate models that simulate the interactions between the atmosphere, oceans, land, and ice. These models consider factors such as greenhouse gas emissions, solar radiation, and natural climate variability. However, they are not exact predictions of the future but rather, simulate climate change based on different assumptions such as greenhouse gas emissions. As climate model projections are associated with uncertainties, storylines are used in this research to represent various scenarios that may emerge given these uncertainties in future projections. **The aim of the storylines is to help readers translate uncertain climate projections into more tangible plausible outcomes or scenarios.** Each storyline represents a plausible (supported by observed and modelled evidence) climate future for the country, or regions within the country. A storyline represents a physically self-consistent unfolding of plausible future events or pathways (Shepherd et al., 2018). **The storyline methodology can spark discussion and thought processes, which can add nuance, structure, and meaning to evidence-based yet hypothetical scenarios.**

In the cases explored as part of this research, the scientific evidence base substantiating the storylines is derived from a retrospective analysis of the evolution and outcomes of similar past El Niño and IOD events, combined with current observed trends. The analysis of likely impacts following the development of a storyline draws on both past examples and future evidence-based projections to substantiate and exemplify the plausible future impacts individuals, communities and societies might face.

Storylines for the East India region

Two storylines were developed for the East India case. The first focuses on the near-term timeframe (2-10 years), and the second focuses on a 2°C world. The following sections explore the impact of these storylines.

Storyline 1: near term (2-10 years)	Storyline 2: 2°C global warming
Following a La Niña phase, which will likely last 2-3 years, a transition to an El Niño Pacific event is likely to occur. A positive IOD phase in the Indian Ocean could also be simultaneously triggered.	**Under a 2°C warmer world the Indian Monsoon rainfall is expected to increase. However, ongoing El Niño and La Niña variability and increased magnitude rainfall and temperature responses to El Niño and La Niña is also anticipated.**
This storyline has two subsections which are explored below.	

Datapoints for the retrospective analysis

The impact of this chain of events on the states across East India is explored under the lenses of health, mobility, trade, and security. The following storylines summarise the various plausible scenarios and the implications of this chain of events on the study region.

The information that substantiates these storylines is derived from a retrospective analysis of past El Niño and IOD events which exhibited similar conditions (see Figure 2 below). Using this information and combining with current trends seen, the following storylines are developed. Therefore, in the analysis, information from the past is drawn upon to substantiate and exemplify plausible future scenarios. The following events have been used to predominantly draw analysis from:

Dates	Configuration of El Niño and positive IOD	Main hydrometeorological events experienced in the region
1997-98	Dominant El Niño event and positive IOD.	Hot and dry conditions.
2002-03	El Niño event led to severe drought during the 2002 monsoon season. Later, positive IOD developed which offset the impacts of the El Niño event.	Decreased precipitation.
2009-10	Dominant El Niño and neutral IOD.	Extreme heat.
2015-2016	El Niño and weak positive IOD.	Severe drought and extreme temperatures.
2019	Enhanced monsoon season due to strong positive IOD, but also El Niño event.	**Heavy rainfall and flooding**, compounded by **severe tropical cyclone** on the west coast of India enhancing monsoon rains.

The data drawn upon to substantiate the understanding of the potential impacts of the developed storylines and formulate an understanding of the plausible impacts that might be seen under both storylines 1 and 2 for this research, spans a range of sources. In the analysis, academic peer reviewed literature, news reports, humanitarian bulletins and also government and non-governmental actor reports were drawn upon. This process was substantiated with findings from a systematic review and then cross-referenced by interactive workshops with FCDO expert practitioners across the region of study. More information on the process can be found in the summary report and methodology document that form part of this report series.

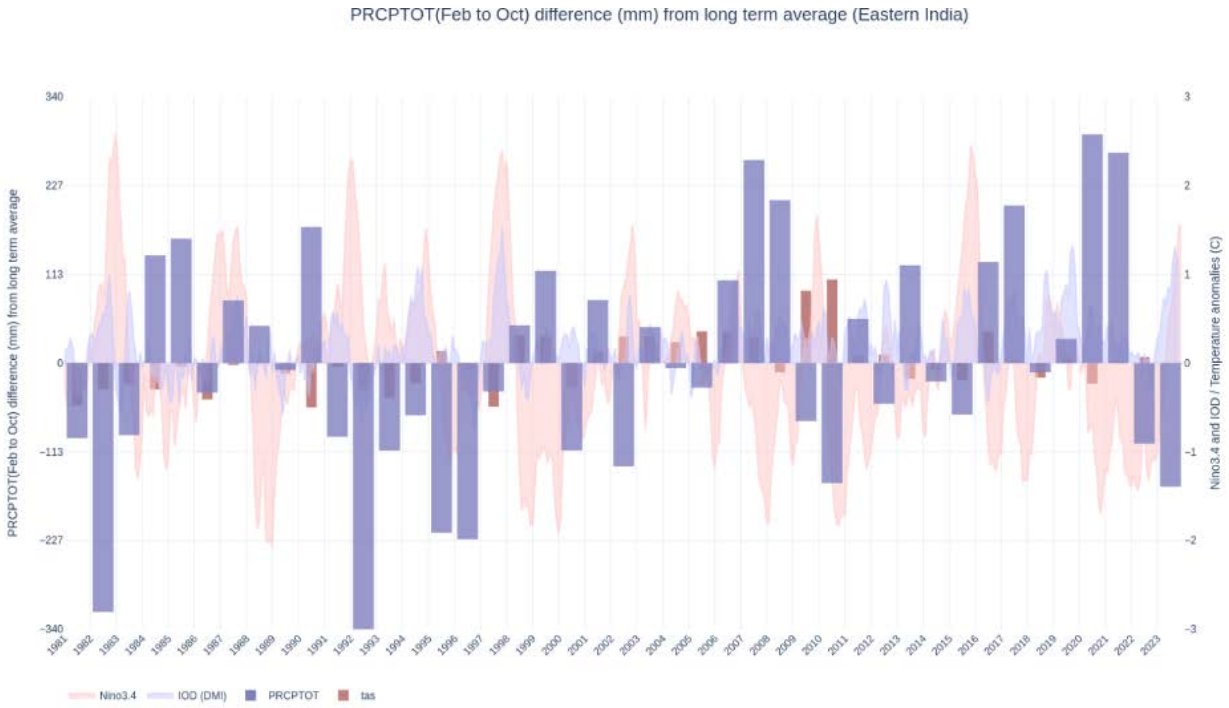


Figure 2: February to October total rainfall anomalies (in mm of normal) (1981-2022, blue bars), temperature anomalies (C) (red bars), ENSO Nino3.4 index where values > 0.5 indicate El Niño conditions and values less than −0.5 show La Niña conditions (pink curve), IOD DMI index showing positive and negative phases of IOD (blue curve).

Storyline 1: near term (2-10 years)

Storyline 1: Following a La Niña phase, which will likely last 2-3 years, a transition to an El Niño Pacific event will likely occur. A positive IOD phase in the Indian Ocean could also be simultaneously triggered.

This storyline is presented in two subsections, each considering the dominance of either El Niño or positive IOD conditions across the Pacific and Indian Oceans.

These are depicted in the table below:

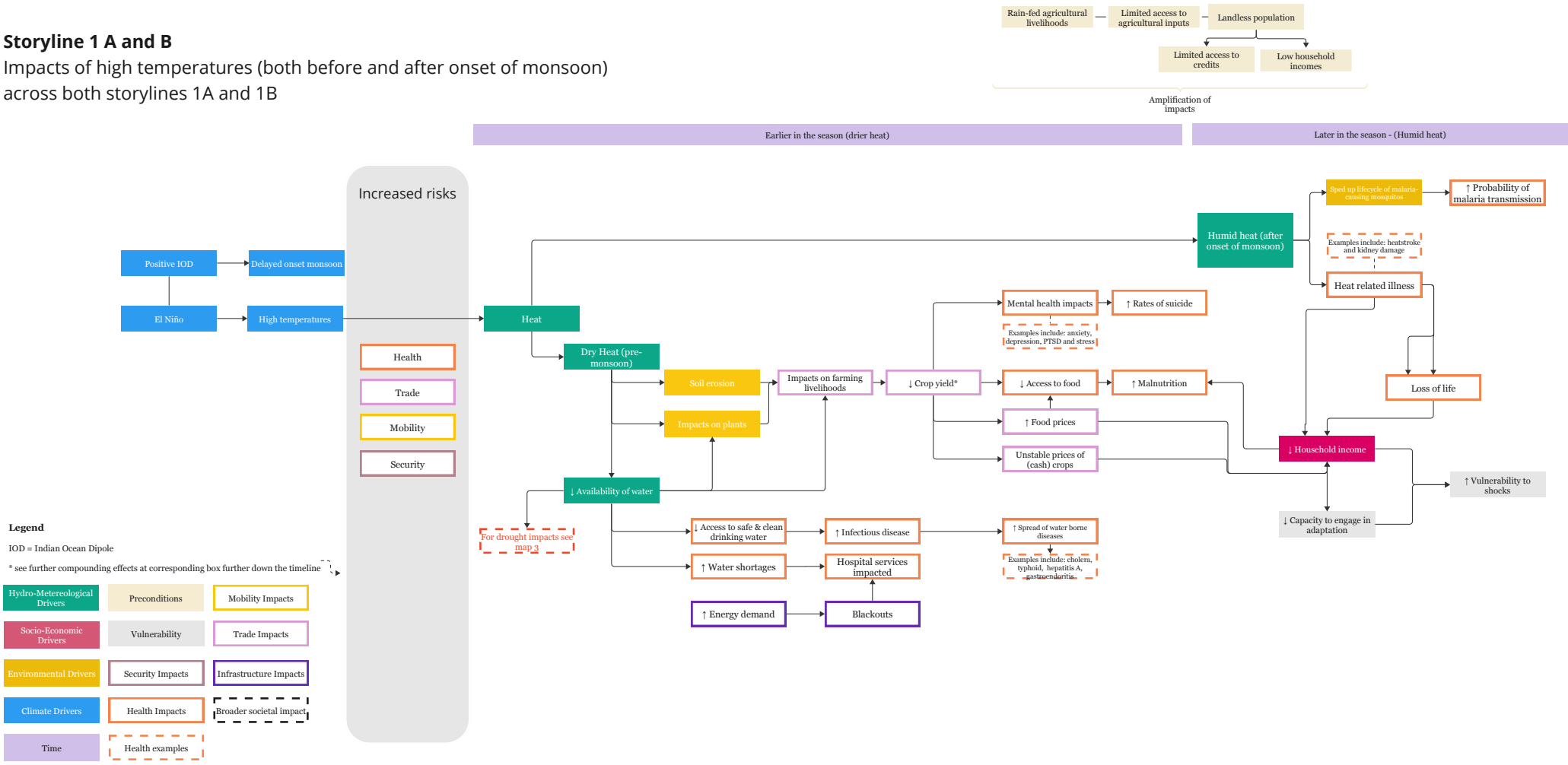
Phase	Impact	Associated impacts
Following a La Niña period lasting 2-3 years, transition to El Niño and positive IOD	Sub storyline 1 A: If the effects of the positive IOD are more dominant than the El Niño, increased high temperatures are likely which will persist throughout the seasons. This is combined with a delayed monsoon which is wetter than normal. Once the monsoon arrives, there is also a likelihood of increased precipitation and flooding during the wetter monsoon season.	▪ Heat extremes ▪ Flooding later in the period due to wetter and delayed monsoon
	Sub storyline 1 B: If the effect of El Niño is more dominant than the IOD, increased high temperatures are likely which will persist throughout the seasons. This is combined with a delayed monsoon which is drier than normal.	▪ Heat extremes throughout. ▪ Drought conditions are exacerbated by drier monsoon

Causal maps are visual depictions of the interactions between different climate hazards and impacts described in this research. The following pages present the causal maps which were developed as part of the process to highlight the connectedness and complexity of the impacts.

Map 1.1 The impacts of high temperatures (present in both Storyline 1A and 1B)

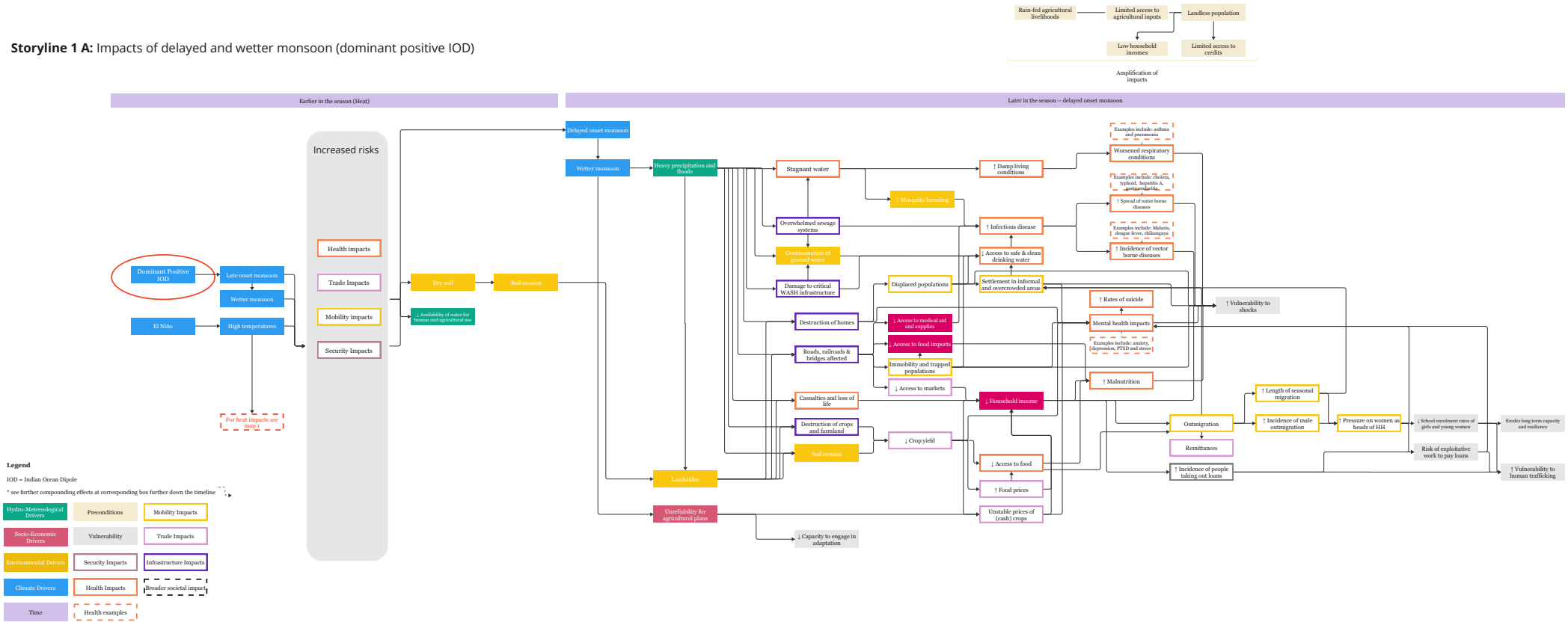
Storyline 1 A and B

Impacts of high temperatures (both before and after onset of monsoon) across both storylines 1A and 1B



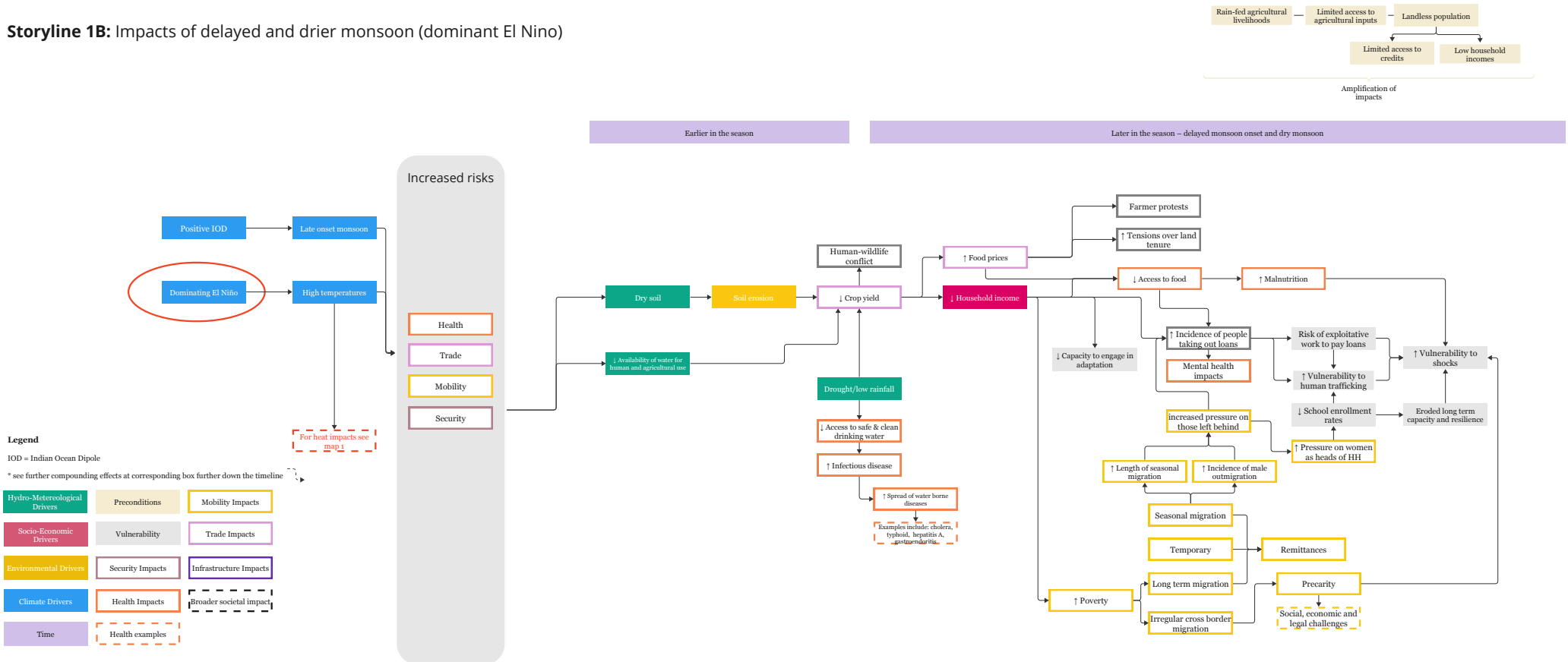
Map 1.2 The impacts of a dominant positive IOD phase

Storyline 1 A: Impacts of delayed and wetter monsoon (dominant positive IOD)



Map 1.3 The impacts of a dominant El Niño phase

Storyline 1B: Impacts of delayed and drier monsoon (dominant El Nino)



Storyline 2:
2°C increase in global temperatures above pre-industrial levels

Under a 2°C warmer world we expect the Indian monsoon rainfall to increase. However, we also anticipate ongoing El Niño and La Niña variability and increased magnitude rainfall and temperature responses to El Niño and La Niña.

Phase	Impact	Associated impacts
Indian monsoon rainfall to increase **Ongoing El Niño and La Niña variability**	Hotter temperatures throughout the seasons. La Niña conditions in a 2°C storyline would increase the probability of very extensive (long season, large amounts) and intense rainfall (high rainfall intensities). The dry season would be significantly hotter (1-2°C warmer than current) because of global warming. Decreased snow would reduce river flows, though high temperatures can produce rapid snow melt in spring, resulting in flooding.	▪ Heat extremes ▪ Flooding later in the period due to wetter and delayed monsoon ▪ Decreased river flows
Increased magnitude rainfall and temperature responses to El Niño and La Niña	Hotter temperatures throughout the seasons. An El Niño event following a La Niña period would likely be hotter than during the preceding La Niña years, particularly during the pre-monsoon season. While the magnitude of meteorological drought (lack of rain) may not be unprecedented, the combination of high temperatures, reduced snow melt in rivers, and low rainfall would result in much **more intense hydrological and agricultural drought** than the region currently experiences.	▪ Heat extremes throughout ▪ Drought conditions (hydrometeorological and agricultural)

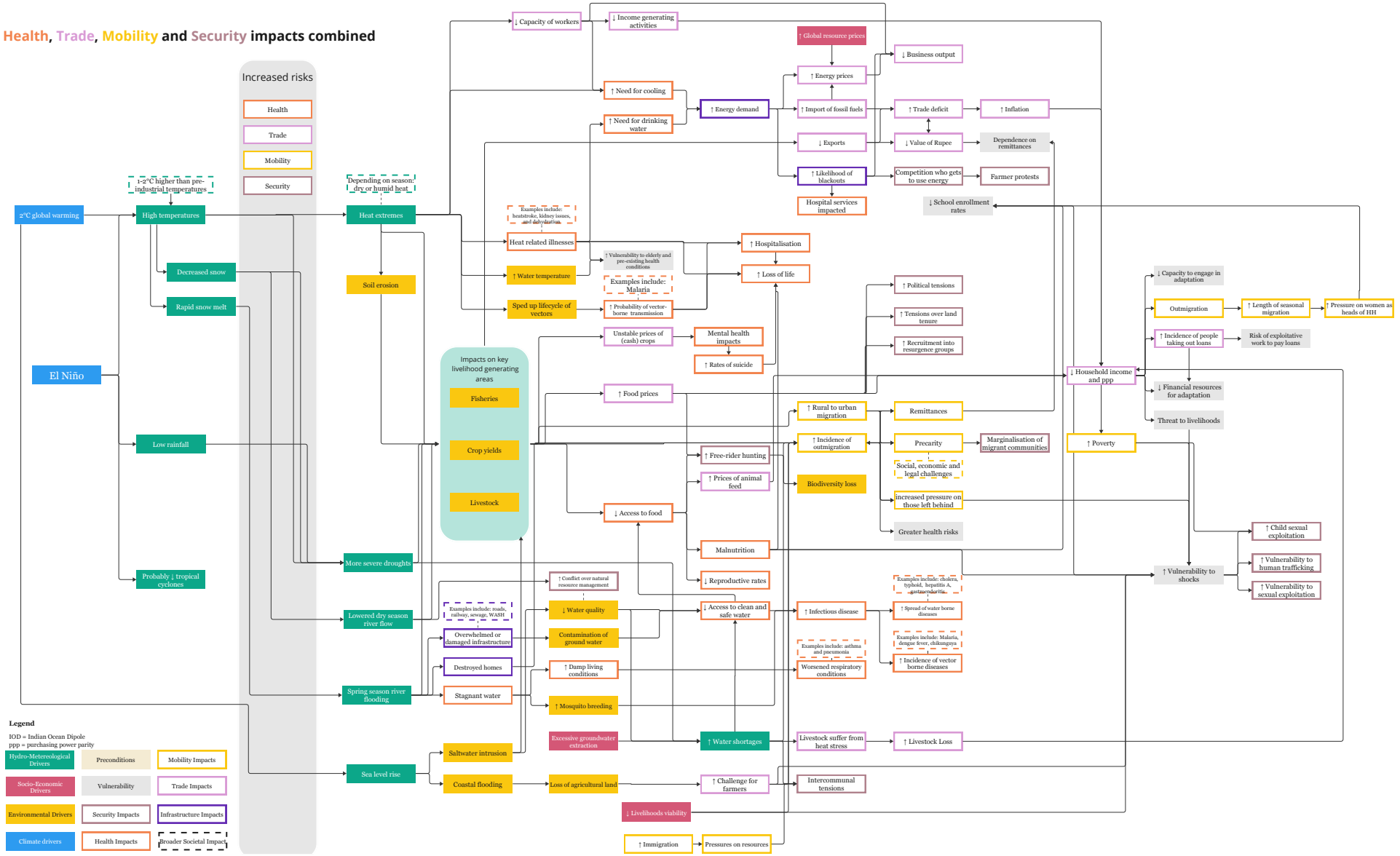
The causal map for Storyline 2 is presented below:

Storyline 2°C: El Niño

Hotter temperatures throughout.

*An **El Niño** event following a La Niña period would more likely be **very hot, particularly pre-monsoon**.*
*While the magnitude of meteorological **drought** (lack of rain) may not be unprecedented, the combination of **high temperatures, reduced snow melt in rivers, and low rainfall** would result in much more intense hydrological and agricultural drought than the region currently experiences.*

Health, Trade, Mobility and Security impacts combined



Impacts

Impacts on health

Summary of impacts on health

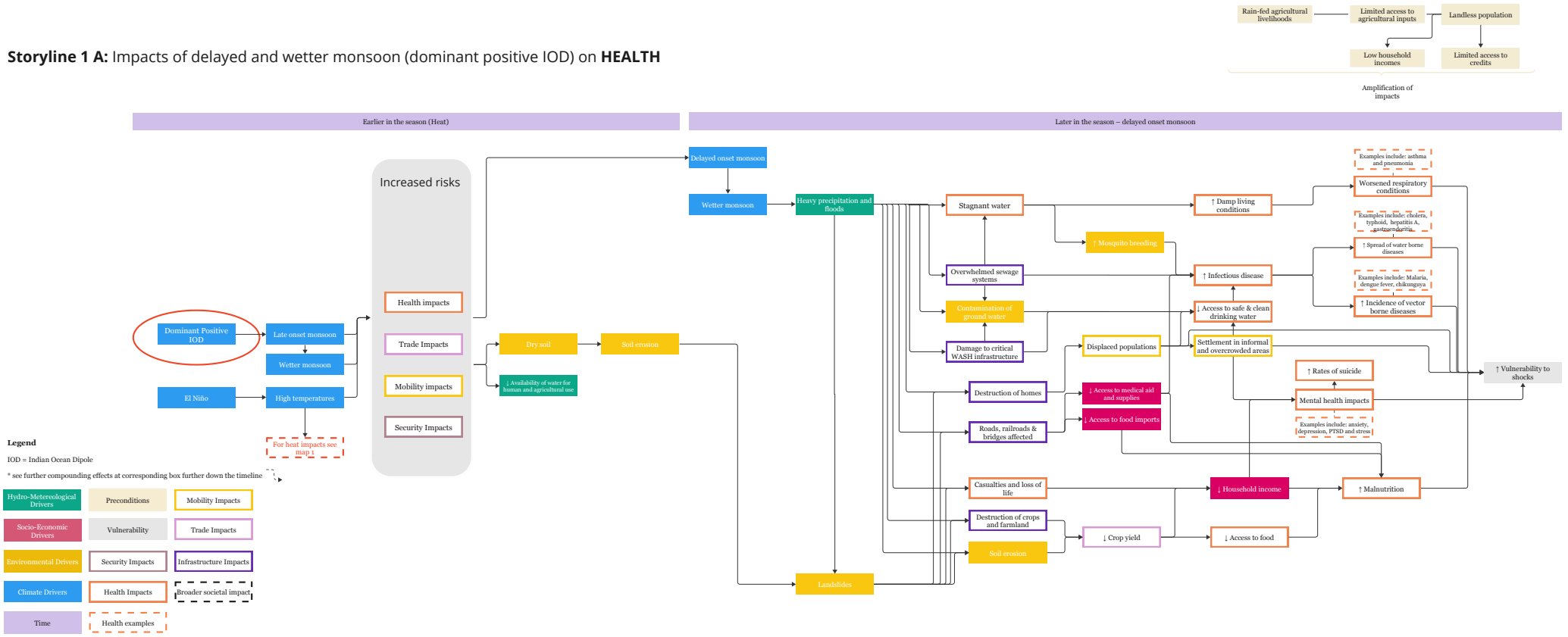
Under Storyline 1A and 1B, impacts on health could be seen in the following ways:

- The impacts of increased precipitation and associated flooding may lead to both increased and decreased agricultural production across states, leading to differentiated nutrition impacts. However, positive effects in India are minor and only found with a positive IOD.
- Due to flooding and ground water contamination from a wetter monsoon, the region could see an increase in the transmission of infectious waterborne diseases.
- The increase in heavy rains and floods could impact vector-borne diseases, driven by changes in breeding sites, which could modify the burden of malaria, dengue, and chikungunya diseases.
- Mental health challenges associated with a disrupted monsoon season, including anxiety and depression, could further impact populations in the region in the future.
- Rising temperatures associated with droughts can lead to heatstroke, kidney damage and other heat-related illnesses.
- Increased prevalence of drought can exacerbate food insecurity and lead to malnutrition.

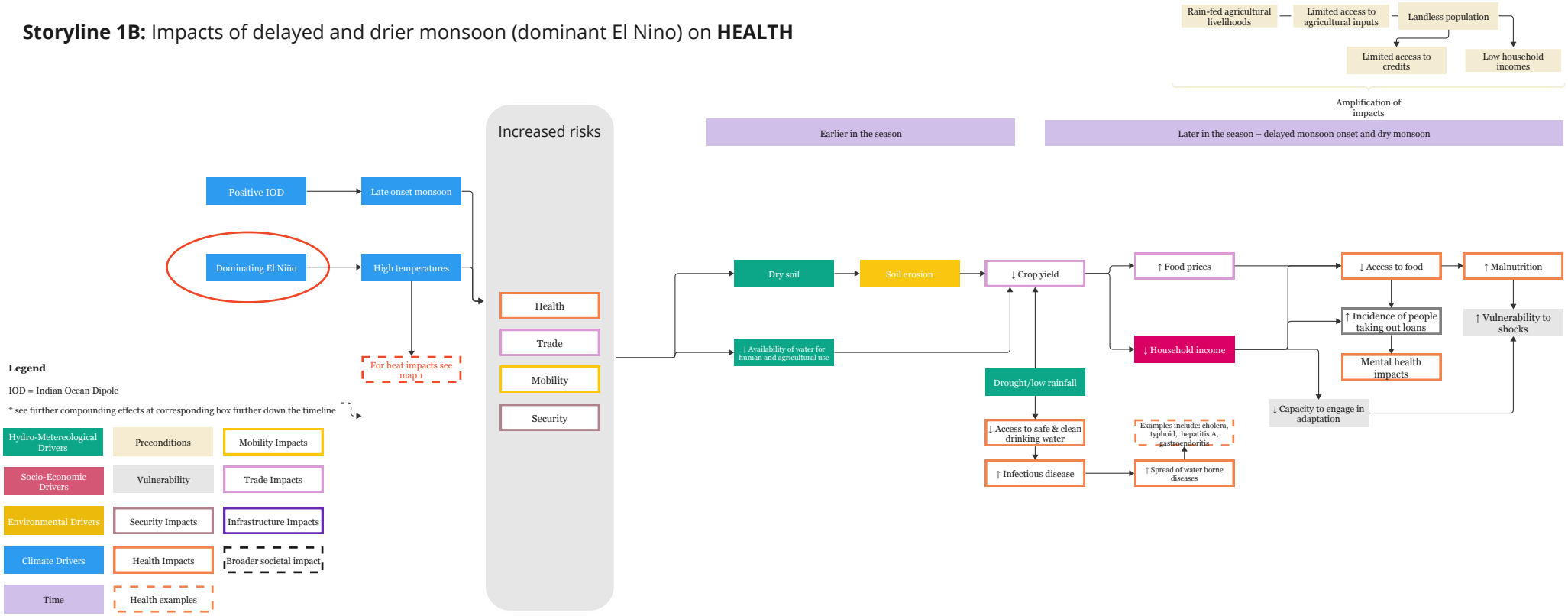
UnderStoryline 2, impacts on health could be seen in the following ways:

- Warmer El Niño conditions could be associated with increased child malnutrition across the region.
- Increase in temperatures and heatwaves could affect vector-borne disease risk in complex ways

Storyline 1 A: Impacts of delayed and wetter monsoon (dominant positive IOD) on **HEALTH**



Storyline 1B: Impacts of delayed and drier monsoon (dominant El Nino) on **HEALTH**



Impacts on health under Storyline 1

Under Storyline 1A, if the influence of the **positive IOD phase is dominant**, it could lead to an **increased incidence of heavy precipitation and floods.** This could have **impacts on health** in several ways:

LOCAL IMPACTS OF STORYLINE ON STUDY REGION

The impacts of increased precipitation and associated flooding may lead to both increased and decreased agricultural production across states, leading to differentiated nutrition impacts. However, positive effects in India are minor and only found with a positive IOD.

Frequent floods in India intensify vulnerability among rural communities reliant on agriculture. With reduced agricultural output, weakened purchasing power and limited employment, floods exacerbate poverty, hunger, and malnutrition threats. Over 60 per cent of India's rural populace depends on agriculture for livelihood, magnifying the impact of floods on rural well-being (Sam et al. 2017). Floods can damage crops and disrupt food supplies, leading to malnutrition and essential vitamin and mineral deficiencies. Disruptions to transportation and healthcare services can make it difficult to access medical care and food in less accessible regions. However, one systematic review found positive effects of IOD on production in the southern and eastern coastal areas of India, with the highest correlated documented in the state of Kerala, yet negative impacts on production elsewhere in the country (Floridi et al. in press).

- **Example:** A study on child malnutrition and recurrent flooding in rural eastern India indicates that children in households affected by floods were more likely to experience stunting than those in non-affected households (adjusted prevalence ratio 1.60; 95 per cent CI 1.05 to 2.44). Additionally, the prevalence of underweight children was higher in flooded communities (adjusted prevalence ratio 1.86; 95 per cent CI 1.04 to 3.30). Exposure to floods is associated with long-term malnutrition in rural communities of Odisha, India, particularly among children who encountered floods during their first year of life, leading to elevated levels of chronic malnutrition (Rodriguez-Llanes et al. 2011).

Due to flooding and ground water contamination from a wetter monsoon, the region could see an increase in the transmission of infectious waterborne diseases.

Excessive rainfall amplifies flooding severity, contaminating groundwater and heightening waterborne disease risks (Andrade et. Al 2018). Overwhelmed sewage systems and contaminated water sources are a particular risk, especially if there are disruptions in water treatment and water storage protocols. This can lead to outbreaks of waterborne diseases like cholera, typhoid, and diarrhoea (Sojobi and Zayed, 2022). However, there are also regions in southeast Asia where excess rain can wash out the pathogens, generating less waterborne risk.

- **Example:** In 2022, people across 14 flood-affected districts of Odisha reported over 900 cases of diarrhoea and other water-borne infectious diseases. These impacts were compounded by the proximity of living conditions, lack of WASH facilities and other health risks (Telegraph of India, 2022).

The increase in heavy rains and floods could impact vector-borne diseases, driven by changes in breeding sites, which could modify the burden of malaria, dengue, and chikungunya diseases.

The stagnant water from floods could create breeding sites for mosquitos, which are carriers of vector-borne diseases such as malaria, dengue fever, and chikungunya (Sharma et al., 2022). While heavy rainfall can lead to stagnant water pools which are ideal for mosquito breeding, a delayed monsoon might initially reduce mosquito populations due to a lack of suitable breeding sites. These variations in mosquito population could lead to outbreaks of malaria and dengue.

- **Example:** In Bhubaneswar, the capital of Odisha, heavy rains during the monsoon season often led to sudden surges in dengue cases. The increased rainfall creates stagnant water in areas with poor drainage, such as urban slums and low-lying areas, where mosquitoes thrive. Additionally, the city's rapid urbanization and construction activities contribute to the accumulation of water in construction sites, further exacerbating the problem (Parihar et al., 2022). In addition, floods and landslides in Odisha in 2002 caused an increase in the amount of stagnant water becoming large breeding sites for Aedes mosquito, leading to surges of dengue in the region (ACAPS, 2022).

Mental health challenges associated with a disrupted monsoon season, including anxiety and depression, could further impact populations in the region in the future.

Heavy rains and floods have devastating impacts, particularly in regions like India. In eastern India, climate change exacerbates the challenges faced by farmers, contributing to suicides and economic losses (Carleton, 2017). Suicides increase during the agricultural growing season, while frequent cyclones and flooding in tropical regions make sustainable agriculture difficult. People in flood-prone coastal areas suffer from mental health pressures such as acute stress, sleep disorders, PTSD, anxiety, suicidal ideation, and depression after cyclones. These disasters not only affect livelihoods but take a toll on mental health, especially among vulnerable communities like smallholder farmers (Mani et al., 2024). The uncertainty and economic hardships resulting from a disrupted monsoon season in eastern India can lead to anxiety, depression, and stress among farmers and other dependent communities in the region (Talukder et al., 2021).

- **Example:** Heavy rains and floods can cause immense psychological stress due to displacement and loss of property and livelihood. Anxiety, depression, and post-traumatic stress disorder (PTSD) are common among flood survivors in western India (Mani et al., 2024). For example, during the 2022 flooding in Odisha, children were at particular risk of experiencing mental health issues or distress from the climate disaster (ACAPS, 2022).

Under Storyline 1B, if the influence of **El Niño is dominant, drought, heatwaves and other heat effects** negatively impacting individuals and communities across the four states could occur. This could have impacts on **health** in the following ways:

Rising temperatures associated with droughts can lead to heatstroke, kidney damage, and other heat-related illnesses.

Excessive heat in the workplace can lead to various health issues, from mild skin rash to fatal heat stroke. Health impacts include sweating, dehydration, perceptual and motor performance loss, heat exhaustion, and increased accident risk. Chronic effects may worsen the clinical status of those with chronic diseases and cause kidney damage due to daily dehydration. In India, between 2001 and 2005, 3,014 men died from heat-related causes, a number that escalated to 5,157 between 2011 and 2015. For women during the same period, the figures rose from 849 deaths to 1,254 deaths, respectively (Kumar and Singh, 2021).

- **Example:** During the 2015/16 El Niño with weak positive IOD, severe drought and high temperatures were experienced in India. More than 2,300 deaths were reported across the country, with most of the deaths occurring in Andhra Pradesh, Telangana, Punjab, Odisha and Bihar (Guleria & Gupta, 2018). Heatwaves from March to May resulted in the loss of at least 580 lives across India (Imada et al., 2018).

Increased prevalence of drought can exacerbate food insecurity and lead to malnutrition.

Extreme heat in India can significantly impact nutrition, particularly among vulnerable populations. High temperatures can reduce appetite and decrease food intake, exacerbating malnutrition, especially among children and the elderly. Additionally, extreme heat can affect the quality and availability of food, as crops may fail or spoil more quickly in hot conditions. This can result in food shortages and increased prices, further limiting access to nutritious food for those struggling with poverty (Amoddo et al., 2023).

- **Example:** Studies have shown that agricultural yields and farmers' annual incomes plummeted by almost 60 per cent during the 2012-13 drought period in drought-prone districts during El Niño years (Bathla et al. 2020). Additionally, research conducted in Odisha highlights a surge in malnutrition attributed to climate disasters (Vedeld et al., 2014; India express, 2016). In Bihar, where approximately 20 per cent of households are food insecure and nearly half of children under five are stunted, extreme temperatures pose a significant threat to food security. As one of India's major rice-producing states, rice is the primary staple food for most people in Bihar. However, extreme temperatures can adversely affect the productivity of these crops, jeopardizing the region's food sovereignty. Decreased crop yields due to heat stress can exacerbate food insecurity and malnutrition issues, further impacting the health and well-being of Bihar's population (TCI, 2022).

Impacts on health under Storyline 2

Under Storyline 2, health could be impacted in the following ways:

HEAT EXTREMES

Extreme heat can lead to heatstroke, kidney issues, and other heat-related illnesses.

Under 2°C of warming, heatwaves will dramatically increase, with eastern India projected to disproportionately experience rising temperatures, along with central IGP and Malabar (Ravindra et al., 2024). Similar to storyline 1, this challenge will be particularly pronounced among outdoor workers, elderly populations, and those with pre-existing health conditions. Research in occupational heat stress is much needed to determine the health impacts and suitable interventions to protect workers' health, particularly among outdoor workers, elderly populations, and those with pre-existing health conditions who face many health problems due to high heat exposure (Parsons, 2002).

- Continued and increased income disparity, combined with unequal access to electricity, could mean that it is harder for lower income populations to access air conditioning and necessary health care required to mitigate worsened health impacts. In India, nearly 232 million people are at risk of extreme heat due to lack of power for cooling mechanisms like fans (SE4All, 2022).

Warmer El Niño conditions could be associated with increased child malnutrition across the region (Amondo et al., 2023).

The 2015 El Niño event likely contributed significantly to exacerbating global hunger. These findings suggest that ENSO is pivotal in triggering episodic food insecurity in tropical regions, where crop yields are typically suppressed during El Niño years, despite global average yield improvements in extra-tropical areas (Anttila-Hugues et al., 2021).

- In India, extreme heat has the potential to drastically reduce access to food both in the next few weeks and over the coming years. Farmers and local officials estimate that the soaring temperatures will reduce yields by 10–50 per cent this season, and the food ministry slashed its output forecast by six million tons (Kroger and Reeves, 2022).

Increase in temperatures and heatwaves could affect vector-borne disease risk in complex ways.

Research has found that more heatwave events increase the prevalence of chikungunya and dengue diseases in coastal districts, which may be of particular relevance for parts of West Bengal and Odisha, while rates of Japanese encephalitis and malaria increase in interior districts, which may be of relevance for Bihar and Jharkhand (Karmakar and Pradhan, 2019).

- Dengue cases in India documented between 2010–2017 and driven by ENSO were found to occur with a 3–6 month time-lag (Kakarla et al., 2019), suggesting the potential to accurately predict cases based on weather events such as El Niño and particular heatwaves (Ma et al., 2022).

Impacts on trade[1]

Summary of impacts on Trade

Under Storyline 1A and 1B, impacts on trade could be seen in the following ways:

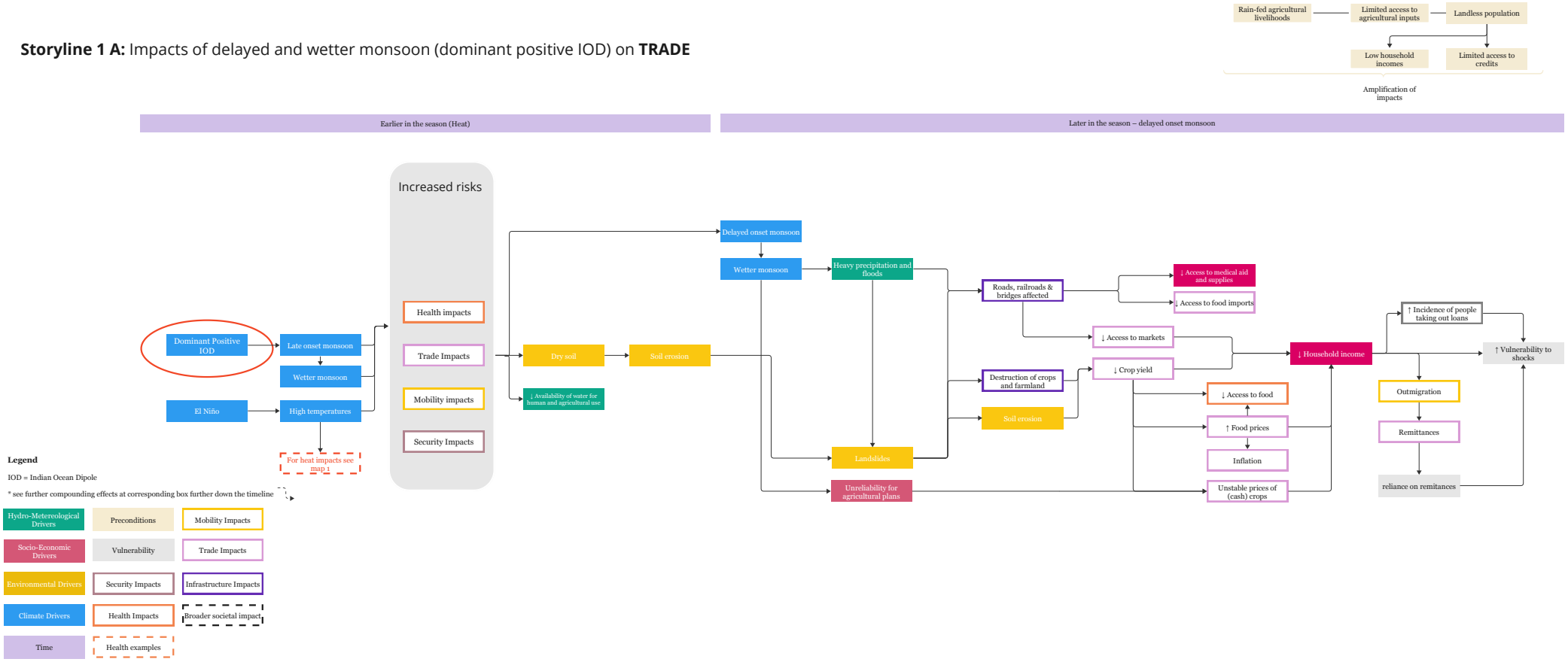
- Floods, wind damage and fallen trees can impact trade through damage to infrastructure such as roads which are essential in the transport of food items to market.
- Floods could damage rice crops and consequently reduce rice yields in the region, leading to a limited rice supply and higher prices both for local populations and of rice intended for export. However, coastal regions may see instead a small positive increase in production (Floridi et al. N.d.)
- Heatwaves and droughts will likely decrease agricultural production, leading to fewer exports and decreasing the livelihoods viability of both farmers and middlemen in the agricultural sector (Bergman, 2022).
- Drought and heatwaves can not only limit agricultural production available for export, but in fact lead to export bans, as was the case in 2022 when the Indian government banned private wheat exports after wheat prices increased over 60 per cent (USIP 2023).
- Heatwaves increase the country's electricity demand for cooling and further threatens India's trade potential by reducing the country's coal stockpiles and contributing to blackouts.

Under Storyline 2, impacts on trade could be seen in the following ways:

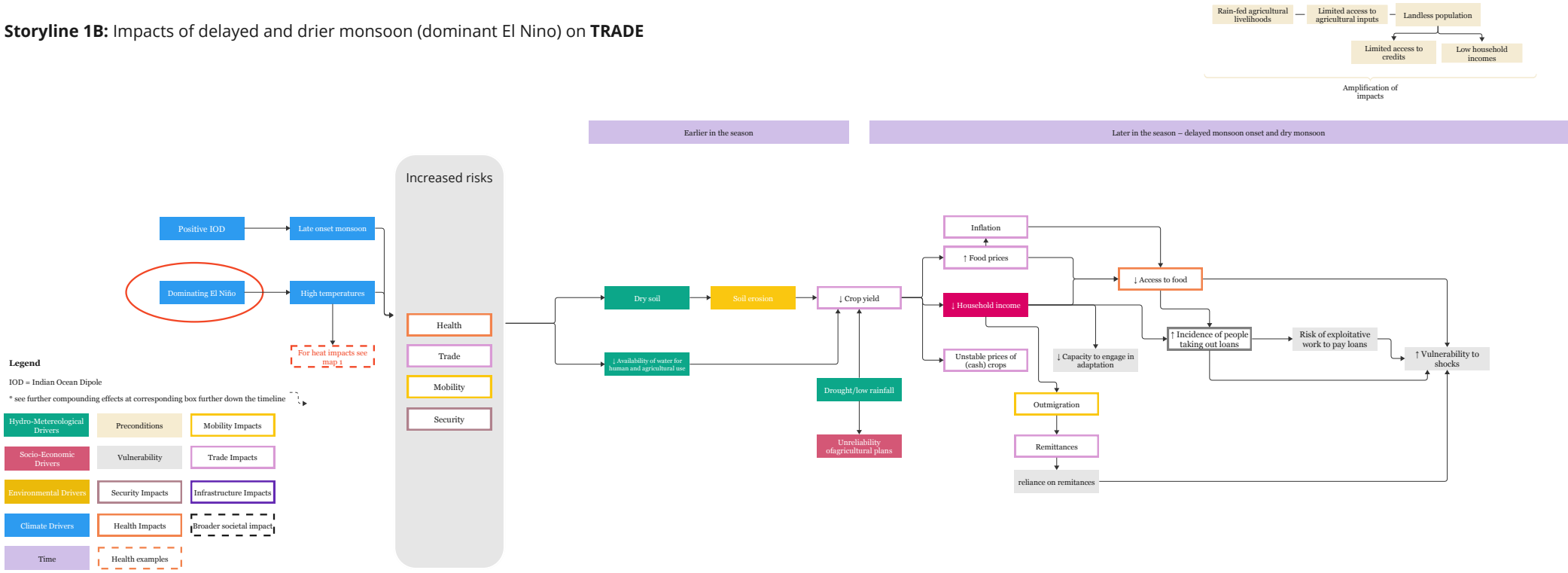
- Implications on crop yields will have knock on impacts for rural farming populations and also for the greater region.
- Communities who are already living with lack of land tenure and access to land, who often rely on non-timber forest products could see a decrease in the income generating activities derived from forested areas

1 It is important to note, the scope of this study was to focus on the key trade impacts. The scope did not enable a review of the broad economic impacts, but storyline approaches could be used for this in future iterations.

Storyline 1 A: Impacts of delayed and wetter monsoon (dominant positive IOD) on **TRADE**



Storyline 1B: Impacts of delayed and drier monsoon (dominant El Nino) on **TRADE**



Impacts on trade under Storyline 1

Under Storyline 1A, if the impacts of the **positive IOD phase are dominant**, there could be an **increased incidence of heavy precipitation and floods**. This could have **impacts on trade** in the following ways.2

LOCAL IMPACTS OF STORYLINE IN THE STUDY REGION

Floods, wind damage, and fallen trees can impact trade through damaging infrastructure such as roads which are essential in the transport of food items to market.

For example, in Odisha and West Bengal in 2021, mainly anecdotal evidence documented how the impacts of Cyclone Yaas left numerous villages suffering from infrastructural damage with supply routes disrupted leaving populations as well as goods trapped (Davies, 2021).

- Roads are the dominant mode of transport in Odisha for passenger and freight transport. A 2019 flood blocked a total of 583 state roads and 1,977 rural roads, stretching over 12,000 km. Blockages were due to uprooting of trees, electric poles and snapping of electric wires and cyclone debris. Road damage costs were estimated to be 46.6 million US dollars while long-term recovery costs were estimated to be 120 million US dollars (ADB, 2019).

Floods could damage rice crops and consequently reduce rice yields in the region, leading to a limited rice supply and higher prices both for local populations and of rice intended for export. However, coastal regions may see instead a small positive increase in production (Floridi et al. N.d.)

India is the world's biggest rice exporter (Duggal and Ali, 2022), and flooding is one of the major climatic events that significantly impacts rice production in the country (Raghu et al., 2022). In the case of reduced export, damage from floods could lead to an increased trade deficit, which would then impact the country's exchange rate, lowering the value of Rupee against foreign currencies.

- Monsoon failures could result in long-term effects on inflation and food prices (Economic Times, 2024). As the majority of rice farmers residing in rainfed areas of India live in absolute poverty, this will have severe impacts on lives and livelihoods as well as trade (Veettil et al., 2021; Ismail et al., 2013).

2 These impacts are under the assumption that the partial, temporary rice export ban would not continue (estimated end is June 2024 by AgriBusiness Global, 2024).

Under Storyline 1B, if the effects of **El Niño are dominant**, it could lead to incidence of **drought, heatwaves and other heat effects** for individuals and communities across the four states. This could have impacts on **trade** in the following ways:

LOCAL IMPACTS OF STORYLINE ON STUDY REGION

Heatwaves and droughts will likely decrease agricultural production, leading to fewer exports and decreasing the livelihoods viability of both farmers and middlemen in the agricultural sector (Bergman, 2022).

- During the entire 2002-2003 El Niño and Positive IOD event monsoon season, there was 19 per cent less rainfall than the long term average, resulting in a severe drought and crop failure, which heavily reduced available crops for export (Gadgil et al., 2005). This was similar to 2015/2016 when a dominant El Niño phase, combined with a weaker positive IOD, meant that severe drought conditions emerged with negative impacts on production and exports.

- Despite more frequent and intense droughts, improvements in irrigation and the increased adoption of improved rice cultivars in rainfed farming systems have lessened the impact of droughts on rice cultivation (Birthal et al., 2015), suggesting that climate impacts can be reduced if properly managed. India's strategy to move from crisis to drought risk management includes agricultural diversification and other measures (Birthal et al., 2015). However, there is disparity in the availability of those adaptation measures (Thapa, 2023).

- Drought and extreme heat-induced crop loss and reduced trade availability could contribute to higher rates of farmer suicide. Globally, India has one of the highest rates of farmer suicide, though this varies considerably between states. The study region has relatively low numbers (Kennedy and King, 2014), yet India has experienced a study increase of farmer suicides in recent years, partially attributed to climate impacts.

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LOCAL IMPACTS OF STORYLINE ON STUDY REGION

Drought and heatwaves can not only limit agricultural production available for export, but lead to export bans, as was the case in 2022 when the Indian government banned private wheat exports after wheat prices increased over 60 per cent (Ober, 2023).

- Climate impacts on wheat in South Asia overall in 2022 impacted global wheat supply, in part due to grain disruptions caused by Russia's invasion of Ukraine (ibid.).

- The hot, dry March in India in 2022 resulted in a three per cent drop in the country's wheat production, with knock-on effects for both trade and food security (Business Standard, 2022).

Heatwaves increase the country's electricity demand for cooling which further threatens India's trade potential by reducing the country's coal stockpiles and contributing to blackouts.

- Coal is the biggest electricity generator in India with 49.1 per cent of total energy production from fuel (Govt of India, 2023). A short-term peak in increased energy demand for air conditioning due to the 2022 heatwave led to higher imports of coal from other countries. This, in turn, led to an emergency law allowing for coal plants to reopen, which had previously been declared cost ineffective and were closed (Anand & Varadhan, 2022).

- High coal prices affected by global developments, such as the Russia-Ukraine war in 2022 (IEA, 2022), impacted local businesses, which struggle to continue operating (Business Standard, 2022).

- Blackouts in 2022 allegedly sparked farmers protests in Punjab, outside the study region. Farmers blockaded roads demanding a minimum of eight hours of power a day for agricultural use (Singh, 2022).

Impacts on trade under Storyline 2

Under Storyline 2, **trade** could be impacted in the following ways:

HEAT EXTREMES AND INCREASED INTENSITY OF HYDROLOGICAL AND AGRICULTURAL DROUGHTS

Implications on crop yields will have knock on impacts for rural farming populations and for the greater region.

Communities who are already living with lack of land tenure and access to land, who often rely on non-timber forest products could see a decrease in the income generating activities that they get from forested areas.

Heat extremes have impacts on forest ecosystems, which, combined with a deficit of precipitation, risks ecosystem decline. For those populations who rely on gathering of mushrooms, berries, medicinal herbs and forest farms, this could significantly impact their trade and economic wellbeing and have larger cultural and societal implications on other sectors.[3]

3 This point arose as an element to consider in the expert practitioner workshops

Impacts on mobility

Summary of impacts on mobility

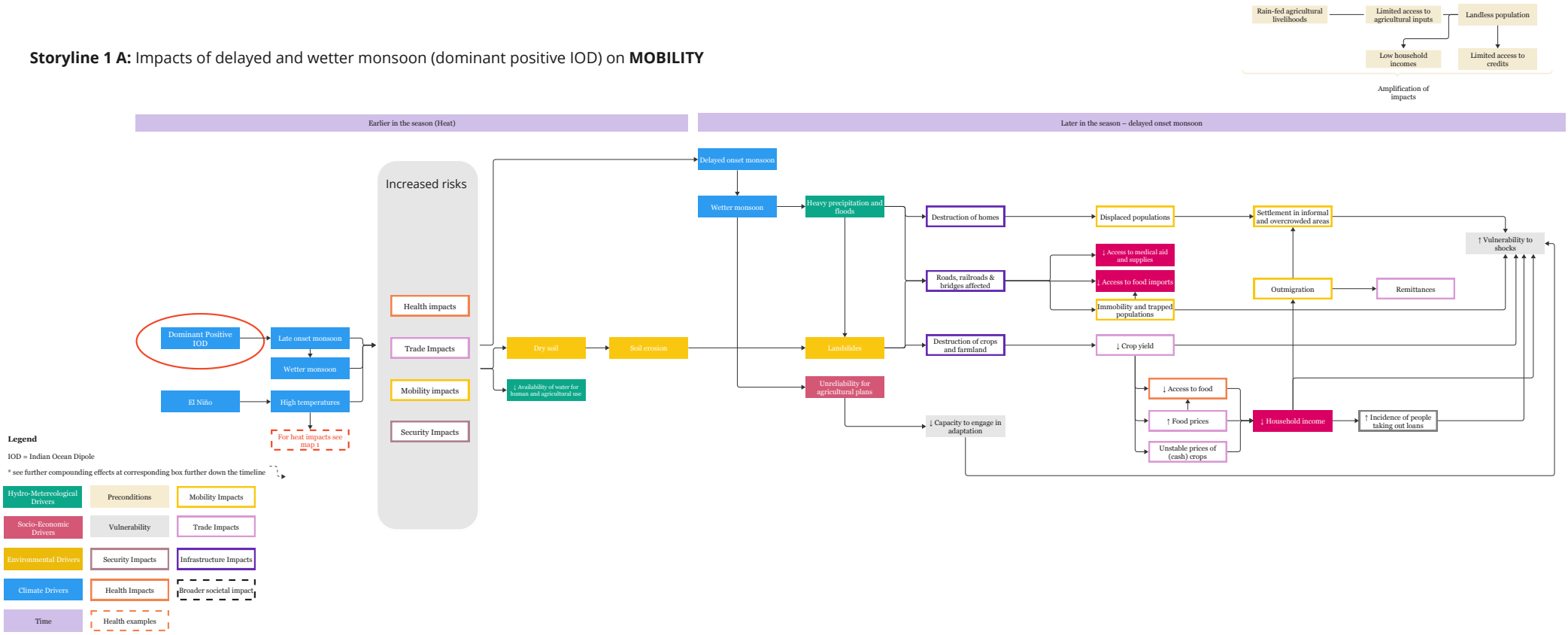
Under Storyline 1A and 1B, impacts on mobility could be seen in the following ways:

- Lead to short term and protracted displacement
- Multiple and consequential displacement which can erode coping capacity and resilience
- The destruction of infrastructure such as roads and bridges from flooding events, which can lead to populations becoming trapped and immobile with limited access to resources or means of communication.
- Increased cross border migration from neighboring countries such as Bangladesh to the Indian study region may occur, due in part to increased flooding from the joint impacts of heavy monsoon rains and sea-level rise (Quencez, 2012; The Nansen Initiative, 2015).
- Under this storyline, increased migration as a form of livelihood diversification or adaptation could occur, as the risk of drought poses a significant threat to subsistence farmers. This is particularly likely as drought is already one of the major drivers of migration for farmers across India (Jha et al. 2017).
- Drought conditions will likely disproportionately increase the rate of migration by those from a marginalized lower caste.

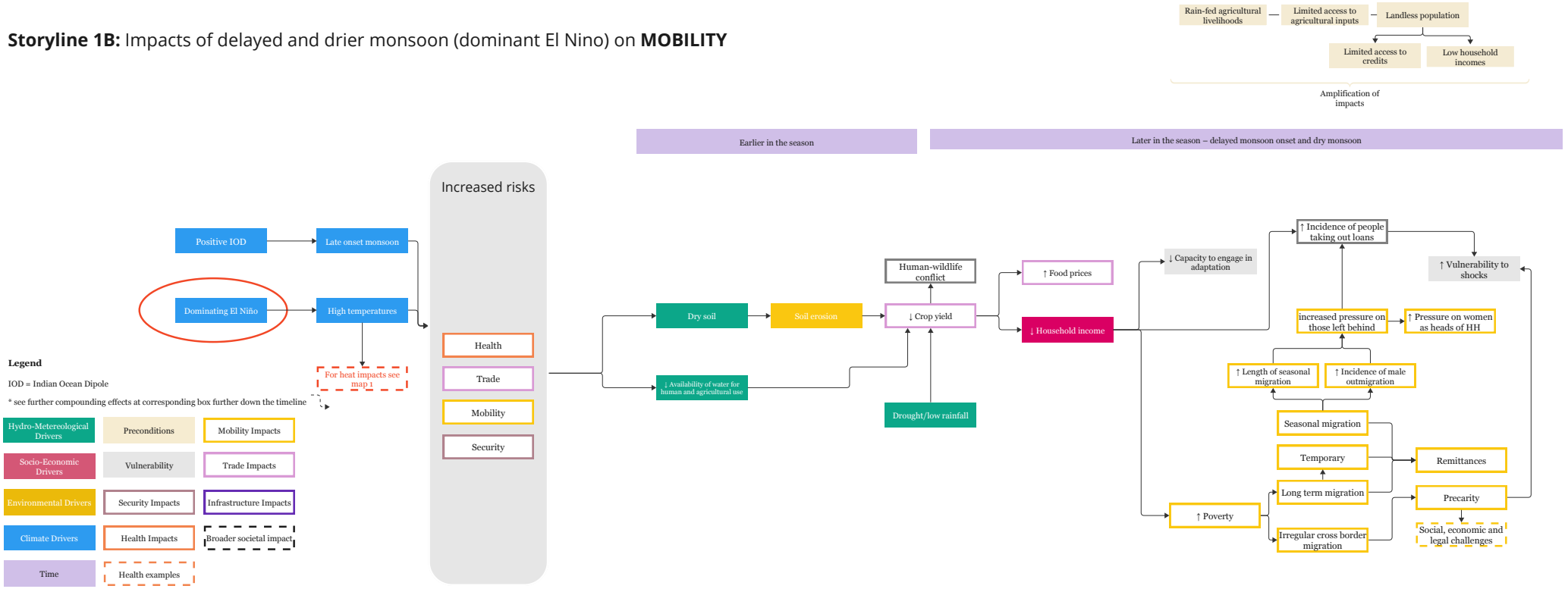
Under Storyline 2, impacts on mobility could be seen in the following ways:

- Migration as a form of searching for livelihood diversification
- Increased duration of seasonal migration
- Climate-induced displacement
- Migration journeys may become more dangerous

Storyline 1 A: Impacts of delayed and wetter monsoon (dominant positive IOD) on **MOBILITY**



Storyline 1B: Impacts of delayed and drier monsoon (dominant El Nino) on **MOBILITY**



Impacts on mobility under Storyline 1

Under Storyline 1A, if the impacts of the **positive IOD phase are dominant**, increased **incidence of heavy precipitation and floods may occur.** This could impact **mobility** in the following ways:

LOCAL IMPACTS OF STORYLINE IN THE STUDY REGION

Flood events that result from heavy precipitation and flooding can cause short-term or protracted displacement.

- India has some of the highest numbers of annual internal displacements, mainly triggered by disasters (IDMC, 2024). Floods account for most of the displacement, with 42.3 million people displaced between 2008 and 2023 (ibid.) Multiple displacements or particularly severe effects occur in part due to multiple flooding events in short succession, which leave people facing the compounding impacts of multiple evacuations and ensuing short or long term displacement (Floodlist, 2019). Such events erode the availability of resources and coping capacity of aid organisations, government agencies and local communities.

- Flood-induced displacement occurred in Odisha during the enhanced and wetter 2019 monsoon season, when the region saw more than 600mm of rain in a period of 24 hours. The flooding led to a number of fatalities and displaced over 45,000 people (ibid.). A similar situation occurred in 2022 when at least 60,000 people in Odisha were displaced due to floods (Davies, 2022).

The destruction of infrastructure such as roads and bridges from flooding events can lead to populations becoming trapped and immobile with limited access to resources or means of communication.

- When essential infrastructure is destroyed, the option of evacuating is taken away. Immobility is important to consider in this storyline as people may be forced to rely on limited supplies and have reduced access to essential services such as health care. During the 2019 cyclone Fani, which destroyed infrastructure for energy and access (e.g. roads and bridges), 3.5 million people across the state of Odisha were left without power and also faced interrupted communication (NASA, 2019). This was compounded by the disruption of road networks to support those in need of assistance. Trapped populations, particularly those most at risk including the elderly and those with disabilities, faced a lack of healthcare, food, water, and other essentials such as durable shelter (Zickgraf, 2020).

LOCAL IMPACTS OF STORYLINE IN THE STUDY REGION

The projected combination of flooding and tropical cyclones may cause people to face multiple displacements and erode their health, wellbeing and resilience.

- During the 2019 enhanced monsoon, El Niño and positive IOD phase, communities across Odisha faced the multiple and cascading impacts of frequent evacuations and displacement from monsoon floods and cyclone events (The New Humanitarian, 2019).

- Displacement due to both flooding and cyclones is projected to increase in India in part due to sea-level rise, which will increase flooding exposure. One study found that if a cyclone similar to 2020 Cyclone Amphan hits the Bay of Bengal in 2100, three times the number of people could be exposed (Mitchell et al., 2022).

Increased cross-border migration from neighbouring countries such as Bangladesh to the Indian study region may occur, due in part to increased flooding from the joint impacts of heavy monsoon rains and sea-level rise (Quencez, 2012; The Nansen Initiative, 2015).

- The Asian Development Bank estimates that migration from Bangladesh to India represents the world's largest international migration (Kishtwari, 2024). This form of incoming migration to the region could lead to increased pressure resources and political tensions, as well as have impacts in terms of human security and security in general. This may be the case due to the high vulnerability and risk profiles of some neighbouring countries, such as Bangladesh, which has highpoverty levels.

- The 2011 floods in Bangladesh led to the cross-border displacement of populations from Bangladesh to India, with impacts including increased levels of securitisation, diminished political relations and reduced human wellbeing (Quencez, 2012).

Under Storyline 1B, if the effects of **El Niño are dominant – drought, heatwaves and other heat effects** for individuals and communities across the four states could increase. This could impact **mobility** in the following ways:

LOCAL IMPACTS OF STORYLINE IN THE STUDY REGION

Under this storyline, increased migration as a form of livelihood diversification or adaptation could occur, as the risk of drought poses a significant threat to subsistence farmers. This is particularly likely as drought is already one of the major drivers of migration for farmers across India (Jha et al. 2017).	**Drought conditions will likely disproportionately increase the rate of migration by those from a marginalised lower caste.**
▪ Drought and reduced agricultural yield could result in the increased migration of rural populations to urban and peri-urban areas, building on ongoing migration trends regarding the outmigration of rural communities in India (ibid.).	▪ Research estimates that people from lower castes are at least three times more likely to migrate from particular parts of India (IIED 2022).
▪ This outmigration could have knock on effects for those migrating and the areas receiving them, as well as for households left behind. The western region of West Bengal is particularly drought prone. Rural populations have been seen to frequently migrate eastwards (Debnath and Nayak, 2022; Rogaly et al. 2001). This suggests the potential for inmigration to the study regions as well as outmigration from the region's coastal areas due to sea-level rise and disasters.	▪ In Palamu, Jharkand state, which has experienced heavy drought, one's likelihood of migrating was increased by a shocking 338 per cent if they were from a lower caste (Bharadwaj et al. 2022).
▪ Past trends in the study region show a high number of males practicing outmigration from the regions, with Rarh region and Bankura districts in West Bengal exhibiting particularly high rates (Debnath, Ray, and Nayak 2019). Migration, which can be costly and dangerous, may negatively impact migrants who are already vulnerable and experiencing high levels of poverty and marginalisation. It can also have a negative effect on societal systems, which suffer from the loss of labour, and place additional burdens on women left behind in charge of households (Lei and Desai 2021).	▪ While the poor in India are more likely to engage in temporary rather than permanent migration (Sarkar et al. 2022), the impacts of flooding caused by La Niña and high levels of poverty, in conjunction with drought conditions, may cause people to permanently migrate, as has been documented in some areas (Krishnan 2023), particularly if they cannot envision a viable livelihood for themselves in the study region.

Impacts on mobility under Storyline 2

Under Storyline 2, **mobility** could be impacted in the following ways:

HEAT EXTREMES AND INCREASED INTENSITY OF HYDROLOGICAL AND AGRICULTURAL DROUGHTS

Increased drought has the capacity to compound the reasons people might engage in outmigration from the study region, resulting in more people practicing rural to urban migration across varying durations or distances.	**Increased drought has the capacity to compound the reasons people might engage in outmigration from the study region and result in more people practicing rural to urban migration across a varying duration of time or distances.**	**Migratory journeys will become more dangerous[4]**
▪ Farming livelihoods will likely face continued and exacerbated impacts. These may be intensified by conditions that amplify vulnerability such as fewer rain fed agricultural livelihoods, limited access to credit, low household incomes or lack of land tenure.	▪ Under storyline 2, there is a likelihood that outmigration may be accelerated due to livelihoods rapidly becoming unviable, for example: repeated crop losses or low fishing yields due to the rise in water temperatures. These may be intensified by conditions that amplify vulnerability such as rain fed agricultural livelihoods, limited access to credit, low household incomes or lack of land tenure.	▪ This is partly due to **heat stress** becoming more likely. More **migration will likely take place through undocumented means**, compounding the dangers people face as they may increasingly use smugglers for cross-border migration or be at risk of trafficking. These risks may rise because of increased levels of outmigration (UNODC 2018).

4 This point arose as an element to consider in the expert practitioner workshops

Impacts on security

The security implications presented in this storyline depend on the responses provided to the outlined risks. The impacts of climate risks on security are highly interrelated with pre-existing vulnerabilities related to human security. Adaptation is essential to minimize the likelihood of security risks compounding the potential climate related challenges, and to address underlying causes of vulnerability. While strict security related concerns cannot be predicted, this section attempts to illuminate some of the human security impacts of the storylines. While some light connections are drawn identifying key areas where human security related concerns can act as a threat multiplier for violence and conflict, the analysis here primarily presents the broader context which may intersect with risks related to violence and conflict.

Summary of impacts on security

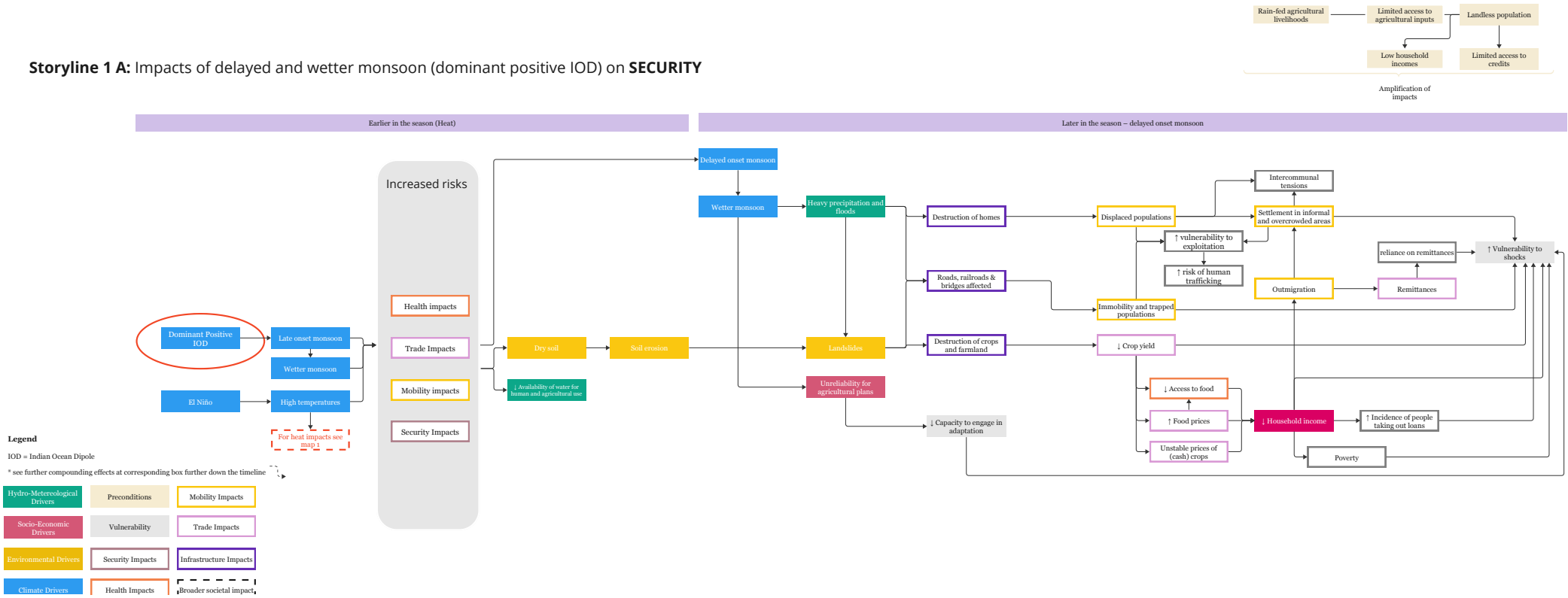
Under Storyline 1A and 1B, impacts on security could be seen in the following ways:

- Flooding and heavy precipitation can significantly impact human security, which can manifest in several ways: physical, economic, water and food security and vulnerability.
- Economic security is threatened during and after flood events, as livelihoods and livelihoods systems are destroyed or interrupted. Reduced economic security can erode coping capacity and adaptive response.
- Food and water security are also at increased risk due to flooding, with impacts on wellbeing and other forms of human security.
- Droughts and floods can increase risks to personal security, including vulnerability to human trafficking.
- Food security is threatened especially for populations with fewer financial resources to implement adaptive measures.
- Economic security will likely be impacted by both drought and heat.
- Rising temperatures and drought can create risks to personal and health security, particularly for rural communities.

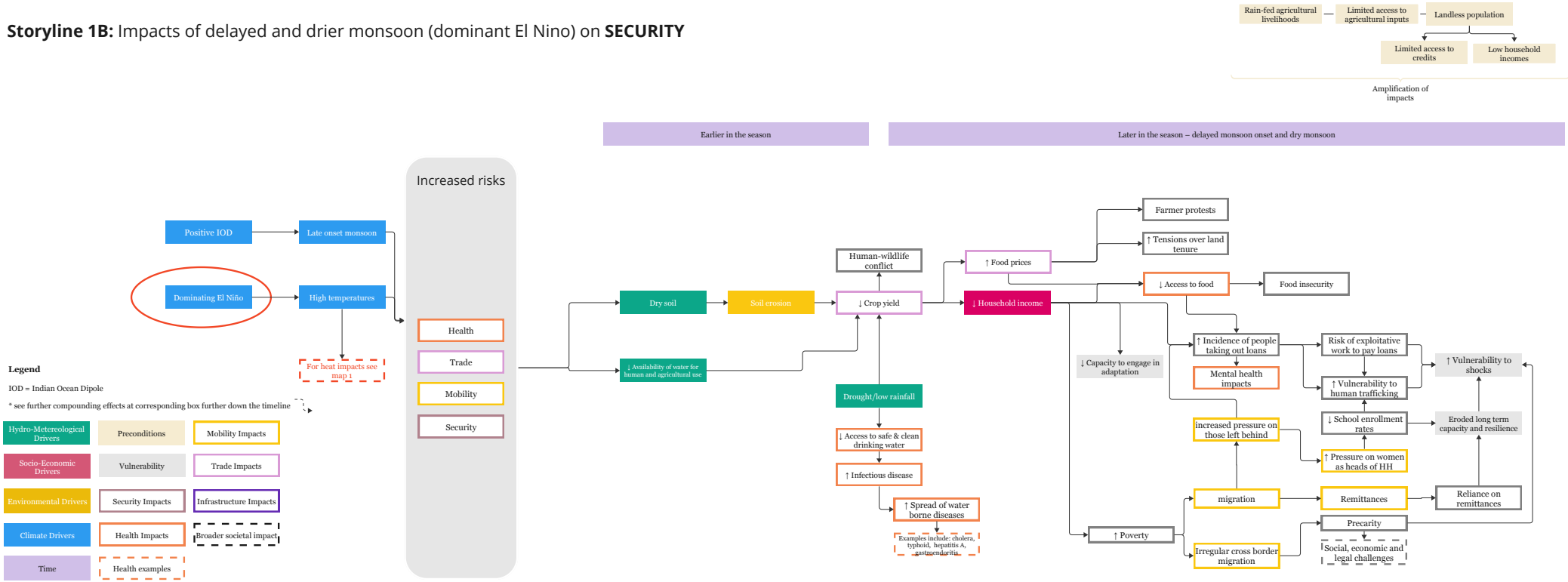
Under Storyline 2, impacts on security could be seen in the following ways:

- The impacts from storyline 1 are exacerbated.
- Conflicts related to border disputes and water in Odisha may be exacerbated as climate change affects the availability and quality of water in the region, with a direct impact on livelihoods, water security and health.

Storyline 1 A: Impacts of delayed and wetter monsoon (dominant positive IOD) on **SECURITY**



Storyline 1B: Impacts of delayed and drier monsoon (dominant El Nino) on **SECURITY**



Impacts on security under Storyline 1

Under Storyline 1A, if the impacts of the **positive IOD phase are dominant,** increased **incidence of heavy precipitation and floods may occur.** This could impact **security** in the following ways:

LOCAL IMPACTS OF STORYLINE IN THE STUDY REGION

Flooding and heavy precipitation can significantly impact human security, which can manifest in several ways: physical, economic, water and food security and vulnerability.

- As documented in past events, one of the most serious risks of flooding is that of physical security, with flood events often leading to high mortality. One example of this was the severe flooding which occurred in 2019 in West Bengal, Odisha and Bihar, when hundreds of people were killed and thousands displaced (Sankar et al., 2021).

Economic security is threatened during and after flood events, as means of livelihhoods are destroyed or interrupted. Reduced economic security can erode coping capacity and adaptive response.

- Future flooding will likely negatively impact economic security in Bihar, Jharkhand, Odisha and West Bengal, as most of the populations in these areas rely on agriculture. Damage and destruction to agricultural lands and property will increase populations' vulnerability through a decreased capacity to cope with the financial implications of climate related hazards.

Food and water security are also at increased risk due to flooding, with impacts on wellbeing and other forms of human security.

- The previously discussed health and food security impacts of flooding can reduce human security.

Floods can increase risks to personal security, including vulnerability to human trafficking.

- Floods are considered a major stressor for household livelihoods, especially as many households in India take out loans ahead of the growing season. As households lose livelihoods, they can be forced to enter exploitative work environments or debt bondage labour. For instance, in West Bengal the impacts of flooding on livelihoods has increased human trafficking, particularly for women and girls (Climate Diplomacy, 2015). This trend is likely to continue under the storyline, given the anticipated ongoing loss of livelihoods.

Under Storyline 1B, if the effects of **El Niño are dominant**, it could lead to incidence of **drought, heatwaves and other heat effects** for individuals and communities across the four states. This could have impacts on **security** in the following ways:

LOCAL IMPACTS OF STORYLINE IN THE STUDY REGION

Under this scenario, food security is threatened, especially for populations with fewer financial resources to implement adaptive measures.

- India's Ministry of Agriculture and Farmer Welfare has estimated that without adaptation, rain-fed rice yields could reduce by 20 per cent by 2050 (Mandavia, 2024). While improved adaptation techniques have decreased the impact of droughts on rice cultivation, access to such adaptation techniques is not always equal. This means marginalized communities may be further exposed to food security risks from drought without being able to access resources and tools for effective adaptation.

Economic security will likely be impacted by both drought and heat.

- The impact of the 2019 heatwave is estimated to have resulted in two weeks of the country's potential income per capita being lost (Kroger et al.). As much of the GDP in Bihar, Jharkhand, Odisha and West Bengal is related to agriculture, there is a high risk that increasing heat will decrease productivity and consequently economic security for households.
- The combination of high prices due to limited resources and unstable livelihoods can have a serious impact on economic security. For instance, during the drought of 2009, while not directly in the case study area, water shortages in Mumbai caused mass water cuts across the city, forcing people to buy water at extremely high prices (Relief Web, 2009). In Mumbai, this resulted in violent protests over water shortages.

Rising temperatures and drought can create risks to personal and health security, particularly for rural communities.

- Between the years of 2000 to 2004 and 2017 to 2022, there was a 55 per cent increase in deaths across India. As communities in the four regions in eastern India are primarily engaging in outdoor work, this increases the risk of deadly exposure to heat under this storyline.
- In 2019, almost 200 people in Bihar region were killed due to extreme heat. To protect outdoor workers, some local districts banned all construction and outdoor work during the hottest periods of the day.

Drought can also increase the risk to personal security through contributing to conditions for more human trafficking.

- In Jharkhand, a 2022 study on climate change, migration, and vulnerability to trafficking showed that 42 per cent of interviewees who had moved from their homes due to drought had experienced forced or bonded labour, or other exploitative environments (Nagaraj, 2022).
- The underdeveloped nature of drought early warning systems in India often leads to relief and support not being provided until the impacts on households and livelihoods are severe. This can contribute to migration. This was the case in 2020 , when more people migrated to find work and became becoming more vulnerable to trafficking (Nagaraj, 2022).

Impacts on security under Storyline 2

Under Storyline 2, **security** could be impacted in the following ways:

HEAT EXTREMES AND INCREASED INTENSITY OF HYDROLOGICAL AND AGRICULTURAL DROUGHTS

Economic and human security will likely be impacted by both drought and heat.

- Already in 2024, eastern India has experienced its hottest April on record, with West Bengal recording the highest number of heatwave days in April for the last 15 years, followed by Odisha, which experienced the worst heat conditions the state has seen in nine years (Patel, 2024). There is a high risk that increasing heat will decrease productivity and thus economic security for households. The ability for outdoor work could decline by 15 per cent, decreasing quality of life for 480 million people and costing 2.8 per cent of GDP by 2050 (Debnath et al., 2023).

- Some research finds a significant coincidence rate between disasters including heatwaves and droughts, and outbreaks of conflict in countries with high ethnic tensions (India was not included) (Schleussner et al., 2016); conflict may also occur in urban areas in relation to extreme heat, compounded by the urban heat island effect and the lack of cooling mechanisms for many urban poor.

- Where armed actors exist, such as in Jharkhand and West Bengal, negative impacts on economic security may connect to an increase in recruitment. While not India specific, there is emerging research demonstrating a connection between livelihood challenges and rising rates of recruitment by armed actors (UNU, 2022).

Food security is threatened especially among populations with lower access to financial resources needed for adaptation.

- Poor communities will be further exposed to food security risks from drought and extreme heat without being able to access resources and tools for effective adaptation. Research shows increasing frequency of heatwaves can reverse India's progress in food security alongside other development goals (Debnath et al., 2023).

Conflicts related to border disputes and water in Odisha, may be exacerbated as climate change affects the availability and quality of water in the region, with a direct impact on livelihoods, water security and health.

- A similar example is the farmer protests in India from in 2021 . While not related to climate change, climate related impacts to human security factors in agricultural areas such as livelihoods, and damage to crops may increase the likelihood of food insecurity and exacerbate tensions.

Suggested adaptation interventions

Adaptation interventions can take a variety of forms and be implemented across different scales, from small community level interventions to largescale national government policy interventions. These can be divided into four windows of opportunity for action:

1. Long term DRR and adaptation
2. Anticipatory action
3. Disaster response
4. Disaster recovery

Importantly, each of these windows of opportunity and interventions timescales provide scope for policy incentives to advocate for different interventions.

The following table summarises an array of interventions that exemplify how action on some of the challenges explored in this report series could be taken, all of which cut across the areas of health, trade, mobility and protection. This information is provided with the aim of sparking thinking on how pathways depicted in the causal maps might be adjusted or even changed, given that they are influenced by a variety of drivers, including actions taken in policy spheres, on the lived environment, and societally at local and global levels.

POTENTIAL FUTURE HAZARDS	SELECTED IMPACTS	CLIMATE ADAPTATION INTERVENTION POINT OR ACTION	TYPE
DROUGHT	Crop failure and food insecurity	**Income support for small-scale farmers.** Introduction of small-scale, affordable drip irrigation, good seeds, and plant nutrition, including switching to crops that give continuous supply with limited processing and logistics, thereby increasing smallholders' income while using less land and water.	Investment in small holder
	Water insecurity	**Dissemination of water purification systems.** Provides a temporary solution to support communities who are being pushed further towards unreliable and unsafe water sources.	Disaster response
		Investment in desalination infrastructure. Early investment in desalination infrastructure, especially in areas projected to see a decrease in river flow and rise in sea level, could provide support for communities struggling to access water.	Medium investment
		Support for transboundary cooperation efforts and the backing of policy incentives to engage in peace-building and cooperation incentives.	National government or policy intervention
	Decreased household income	**Vocational training and education to build skills.** Connect these groups with job markets or entrepreneurship opportunities.	Network and capacity building
	Deteriorated mental health	**Investment and support of social protection programmes** that can identify and support those with increased risk of mental health challenges.	Social protection

POTENTIAL FUTURE HAZARDS	SELECTED IMPACTS	CLIMATE ADAPTATION INTERVENTION POINT OR ACTION	TYPE
HEAT	Heat stress	**Climate-resilient production and system services.** Micro investments in modern technology to improve farm acreage and work capacity of farmers. **Investment in nature-based solutions to extreme heat.** Supporting local governments to invest in planting shade structures and incentivising afforestation could help alleviate the impacts of heat on outdoor workers and vulnerable populations.	Investment (small scale)
	Crop failure	Increasing more equal access to and support in adoption of improved rice cultivars in rainfed farming systems. For more, see similar interventions under drought.	Investment (medium scale)
FLOODS	Destruction of infrastructure	**Flood safety guidance.** Ensure people have access to information on flood risk zones, landslide zones, and other routes which maybe be dangerous to travel along. It is important that information is easily understandable and doesn't need high levels of technology to engage.	Networking and capacity building
	Trapped populations and immobility	**Development and maintenance of early warning infrastructure.** Effective communication systems have the capacity to inform communities of when to take action and the lead time to a hazard Engagement with and development of **early warning early action** triggers and financing for communities.	Anticipatory action and early warnings infrastructure
	Short term displacement	**Early warning communication.** Dissemination of early warning messages to communities at risk of being affected by floods. **Food and water provisioning services for displaced populations.**	Anticipatory action and early warnings
	Protracted displacement	**Income support for displaced populations** to ensure continued livelihood opportunities, decreased risk of exploitation. **Ensure marginalised and vulnerable populations have adequate access to social protection initiatives and programming to meet basic needs.**	Investment (small to medium scale)
		Ensure government recognition of climate displacement and other forms of climate mobility.[5]	National government or policy intervention
	Destruction of crop or livestock	**Evacuation of livestock.** Identification of safe havens or alternative pastureland for animals and/or relocate livestock to elevated grounds. **Early warning systems for early harvest** (wherever possible) to minimise risk to crop yield.	Anticipatory action and early warnings

5 This point arose as an element to consider in the expert practitioner workshops

Recommendations

Storylines can be used inform programmes, strategies and adaptation plans and further data gathering. They provide a useful starting point for discussion and planning and can be further built on through deeper dives together with impacted stakeholders, as well as those with the responsibility and power to take action.

It is recommended to use the storylines and impact information from this report as a discussion tool with national and regional teams and counterparts in government to explore preparedness measures, ideally low-regret options that would benefit local populations under multiple storylines. It is also important to reflect the potential different realities of El Niño or positive IOD dominance, and the impacts nationally. The storylines emphasize the importance of local monitoring of hydro-meteorological conditions, going beyond ENSO or IOD forecasting.

Core recommendations include:

Recommendation 1

Prepare for a future with persistent oscillation between La Niña and El Niño and positive and negative IOD, in an increasingly warmer world with more intense precipitation.

While the storylines highlight the various trajectories of climatological drivers of risk in the region, an overall conclusion is that locally, hydro-meteorological extremes such as floods and drought will persist and likely intensify under global warming. The storylines offer an opportunity to support relevant governments to reflect further on near-term and longer-term impacts of climate variability and climate change in national adaptation plans and disaster risk management strategies and protocols. Strengthening awareness of existing modes of climate variability, and enhancing preparedness and risk reduction now, will support long-term adaptation, as risks are expected to intensify under a global 2°C warming scenario. Many of the impacts observed under the near-and longer term storylines are rooted in local vulnerabilities. This suggests that investment in improvements in food availability and accessibility, education, transportation and local economic systems can help buffer the impacts of extreme hydro-meteorological events influenced by ENSO and IOD in the near future, albeit with limitations. In line with the systematic review, the most robust academic evidence exists for prevention activities for vector-borne diseases, support to increase drought and flood resilience in agricultural systems (particularly for rice farming) and prevention of disaster-related displacement through early evacuation and livelihood support.

Recommendation 2

Monitor climatological conditions at local, national, regional and international levels to design and implement informed action.

Given the potential variability in the next 2-10 years, further aggravated under climate change, it is crucial to monitor conditions to take informed action. Beyond monitoring the various ENSO and IOD indices and forecasting tools, it is crucial to review local conditions. For example, La Niña in the next years may produce high antecedent vulnerabilities to subsequent El Niño/IOD events that can inform policymakers about the potential severity of El Niño and positive IOD impacts. Regularly updating information will be important, as the storylines outline potential impact based on current knowledge, but rapid socioeconomic and climatological tipping points may change dynamics in the near future. The 2023/2024 El Niño and positive IOD phase highlighted the opportunity to use forecasting and monitoring tools, yet also illustrated a lack of proactive action based on the available warnings. While the capacity of governments to act on warnings varies widely across the Indo-Pacific region, it is recommended to engage with local stakeholders and interlocutors to discuss current approaches to monitoring ENSO, IOD and local hydro-meteorological conditions, and the capacity to act based on warning signals.

3

Recommendation

Conduct targeted research and analysis to close key knowledge gaps that currently limit evidence-based policy decisions.

Workshops and background research highlighted key knowledge gaps that are currently limiting the ability of national and regional staff to make evidence-based decisions on FCDO policy and support. It is recommended that further research is considered for the key knowledge gaps raised, to further operationalize the storylines research. Given the short timeframe and specific focus on climatic drivers of different scenarios in the case study areas, some important areas deserve greater attention in subsequent research. These include other sectors that will experience climate impacts, and non-climatic drivers of change such as geopolitical shifts, rapid policy changes, or local dynamics of environmental degradation. The priority knowledge gaps include:

- The Central Dry Zone of Myanmar and certain states in eastern India, are under researched regions (also evidenced in the findings of the systematic review research).[6]
- Environmental degradation (e.g. pollution, deforestation), which was emphasized as a key concern across the workshops and extended to issues of land governance and land grabbing.
- Tipping points and temporal evolution of impacts and adaptation strategies, climatological tipping points and systemic risks.
- Further analysis of social, economic and policy related drivers of change in the case study contexts and the wider region, for example the role of China in the LMR and the wider ASEAN relating to trade and hydroelectric dams .
- Analysis of existing or missing policies in study regions and their likely impact on outcomes (e.g. adaptation policies).
- Analysis of the strength of pathways in the causal maps and described storylines.
- Impacts on additional sectors, such as energy dynamics, infrastructure, and housing..

6 This point arose as an element to consider in the expert practitioner workshops
7 This point arose as an element to consider in the expert practitioner workshops

4 Recommendation

Recognise and embrace the role of understanding and working within complexity when addressing future climate challenges.

Findings on impacts drawn from the storyline methodology have provided an insight into the inherent and underlying complexity and interrelatedness of the challenges populations may face in the future. The causal maps presented across all plausible future storyline scenarios outline the ways in which it is extremely challenging, if not sometimes impossible, to consider impacts in silos or view them as simple. More work remains be done to highlight the interwoven and inextricable connections that underline vulnerability and decreased wellbeing and resilience.

The same can be said regarding complexity of the phenomena being researched, such as El Niño and IOD, whereby anthropogenic drivers such as deforestation, pollution, and resource extraction cannot be divorced from the ensuing implications in a given community. By embracing complexity and acknowledging the role of interconnectedness that is inherent to the socio-ecological systems within which we all reside, future research can create space for more nuanced, contextually appropriate, and innovative information sharing and uptake. This, in turn, can lead to more effective support to practitioners, including helping them identify holistic, long-term sustainable solutions and adaptation interventions.

5 Recommendation

Use the storylines as a discussion tool for preparedness measures within countries and regions.

It is recommended to use the storylines and impact information from this report as a discussion tool with national and regional teams and counterparts in government to explore preparedness measures, ideally low-regret options that would benefit local populations under multiple storylines. In these discussions, it is important to reflect the potential different realities of El Niño or positive IOD dominance, and the impacts nationally. The storylines emphasize the importance of local monitoring of hydro-meteorological conditions, going beyond ENSO or IOD forecasting to obtain as locally accurate information as possible to guide current and future policymaking and practice.

Conclusion

This report has utilised a storyline methodology to understand the role that El Niño Southern Oscillation and the Indian Ocean Dipole could play in the near and longer term future of the Indo-Pacific region. Two storylines were developed based on retrospective analysis to inform potential future impacts and refined through desk research and engagement with FCDO expert practitioners.

This work highlights the clear need and scope for further research to be conducted on the topic in this region given existing evidence gaps. Furthermore, through the use of causal mapping and analysis of four sectors, the report has shown the importance of understanding and engaging with complex systems to better understand the possible future scenarios that may arise. This has presented a variety of points for intervention that bodies such as the FCDO could engage in, which could occur across timelines and windows for opportunity. If the FCDO is to act on these, it is advisable that the four recommendations presented in this research are taken up, and that more complex, systems-based research is commissioned. This research has shown that communities across the Indo-Pacific region face increased vulnerability to shocks as a result of ENSO, IOD and global temperature increases. Substantive effort and initiative are needed to urge governments to take more responsibility and action to minimise the impacts of current and future climate events, as climate change will continue to shape the lives of people in the Indo-Pacific region and globally.

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