CARIAA Collaborative Adaptation Research Initiative in Africa and Asia | ASSAR Adaptation at Scale in Semi-Arid Regions | DECCMA | HI-AWARE

UNDERSTANDING VULNERABILITIES USING A HOTSPOT APPROACH

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CONTEXT-SETTING

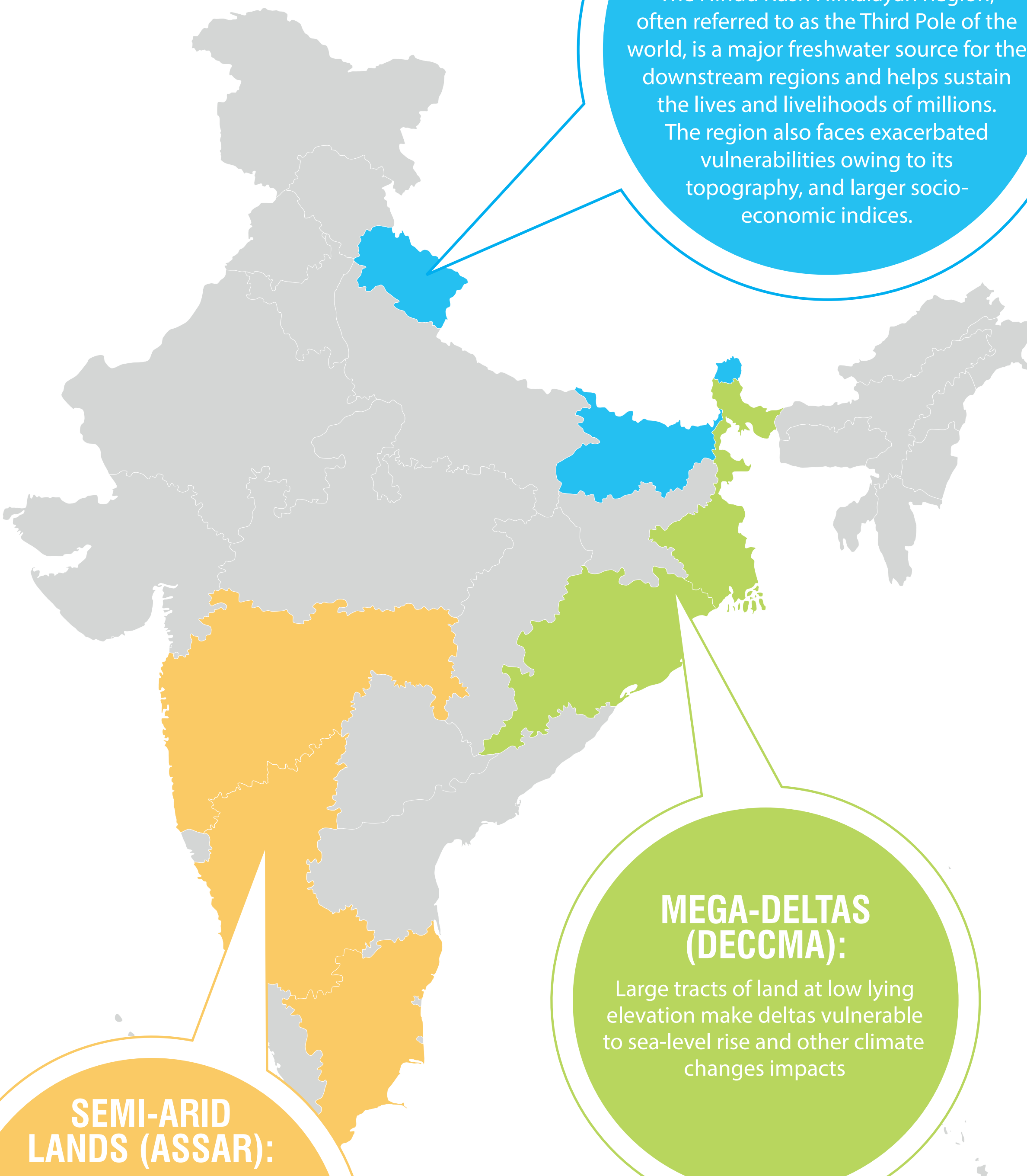
The body of evidence of the observed impacts of climate change on natural and human systems has been increasing with time with the advancement in our understanding of the climate and its system. These impacts however are varied by regions, sectors and people. The varied impact of climate change would lead to exacerbated vulnerabilities in certain regions or "hotspots". The IPCC AR 4 for the first time mentioned hotspots in the context of these large scale global changes being induced largely due to anthropogenic factors of increases in greenhouse gas concentrations (IPCC, 2007).

These hotspots are regions where biophysical impacts coupled with underlying socioeconomic conditions would lead to changing vulnerabilities. Recent published literature defines climate change hotspots as regions where strong climate change signal is combined with a large concentration of vulnerable, poor or marginalised people (Cochrane et. al., 2016). While the biophysical aspects of changes and centres where these changes are likely to be observed is crucial, a large part of the hotspot focus is on the social dimensions regarding implications of these changes and how are societies geared towards responding and adjusting to the likelihood of these changes. It stems from the fact that climate change impacts are disproportionately felt across natural and social systems in different parts of the world. Hence, targeted solutions addressing the needs of the communities in these regions are needed. However, as a step towards providing these solutions, an improved understanding of the coupling of biophysical and socioeconomic conditions is required.

South Asia is a global "climate change hotspot" with data indicating that the region experiences the largest number of disasters in various forms including both slow-onset and rapid events. A large majority of the global poor reside in the region and there are huge gaps in adaptive capacities.

Keeping the hotspot concerns in mind a large 5 year programme on "Collaborative Adaptation Research Initiative in Africa and Asia (CARIAA)" was introduced.

The largest country in South Asia- both in terms of geographical space and demographics, India is a country with large complex multi-hazard environments and climate change hotspots. There are a host of projected impacts to agriculture, water, forests, and coastal regions. In India, the CARIAA focus is on the semi-arids in the western and southern parts of the country, the deltas in the east and the mountain systems in the north. These hotspots in India are defined based on the unique climate signals that surround these regions and the vast number of people and their livelihoods being affected, including a large proportion of the population that is poor and extremely vulnerable. Work in these hotspots were supported with the underlying objectives to enhance our understanding on the various surrounding, interacting issues and to find solutions to improve the well-being of people residing in these hotspots, especially the most vulnerable.



MOUNTAIN SYSTEMS/ RIVER BASINS (HI-AWARE)*:

The Hindu Kush Himalayan Region, often referred to as the Third Pole of the world, is a major freshwater source for the downstream regions and helps sustain the lives and livelihoods of millions. The region also faces exacerbated vulnerabilities owing to its topography, and larger socio-economic indices.

MEGA-DELTAS (DECCMA):

Large tracts of land at low lying elevation make deltas vulnerable to sea-level rise and other climate changes impacts

SEMI-ARID LANDS (ASSAR):

semi-arid regions of are particularly vulnerable to climate-related impacts and risks. These climate-change hot-spots are highly dynamic systems that already experience harsh climates, adverse environmental change, and a relative paucity of natural resources

* This report presents data from Uttarakhand & Sikkim

MOUNTAIN SYSTEMS HOTSPOTS IN INDIA

Glacier and snow-pack dependent river basins – Himalayan Adaptation, Water and Resilience (HI-AWARE) Research

Hotspot Description

The Hindu Kush Himalayan (HKH) region is the source for numerous rivers that traverse through these undulating lands and into their downstream regions, serving as a lifeline to countless unique ecosystems, their flora and fauna, and the millions of people and their culture. Often remarked as the Third Pole, the HKH region, faces numerous threats induced due to changing climate. The arduous terrain, uneven development, and the biophysical impacts result in a coupled impact leading to conditions of vulnerabilities.

What have we found?

- **Mountain systems are extremely vulnerable to the consequences of climate change**

Results from models indicate a rather higher rate of increase in temperatures in the mountain regions compared to the plains. While there are no clear trends in the overall precipitation change, extreme events have increased and the threats due to the increase have been multi-fold.

Uneven developmental patterns in conjuncture with rising biophysical exposure, validated through HI-AWARE's research, which indicate a a warming of 2.1 ± 0.1 °C in the high mountains of Asia with a global temperature rise of 1.5°C (Kraaijenbrink et al., 2017), are making mountain ecosystems vulnerable to current and future changes in the climate A population that is dependent on climate sensitive livelihoods, including rain-fed

Where are we working?

Given this context, as part of this research, in India we are working in the Upper Ganga, Gandaki and the Teesta catchments. The study areas within these basins have been administratively limited to the states of Uttarakhand and Sikkim.

What are we working towards?

HI-AWARE aims to enhance the adaptive capacities and climate resilience of poor and vulnerable women, men, and children living in the mountains and flood plains of the Indus, Ganges, and Brahmaputra river basins. It seeks to do this through the development of robust evidence to inform people-centred and gender-inclusive climate change adaptation policies and practices for improving livelihoods.

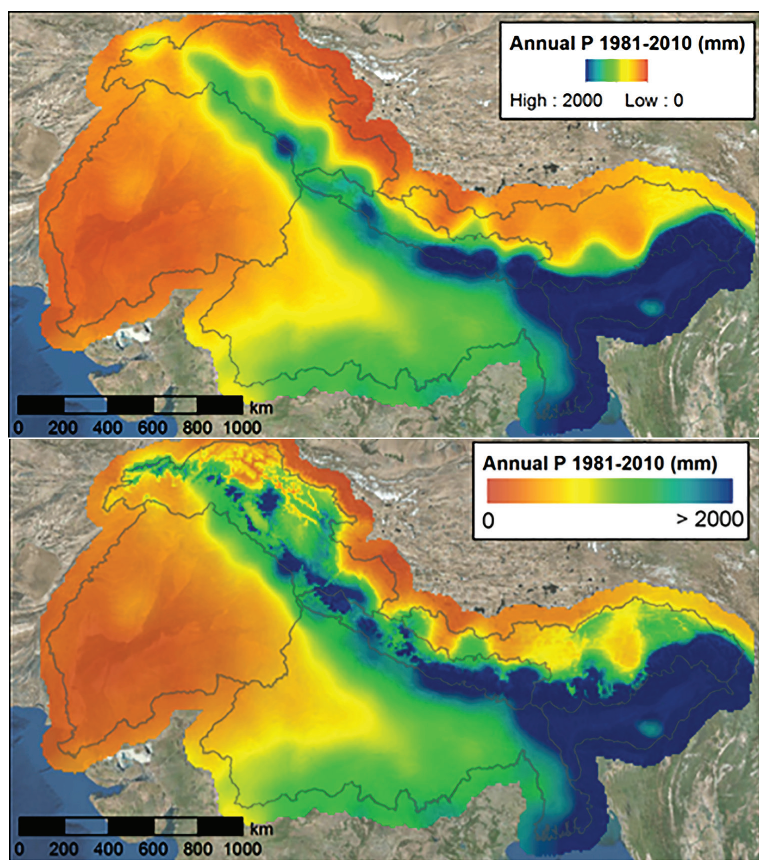


Figure 1: High resolution historical precipitation data - Corrected versus Uncorrected (1981-2010)

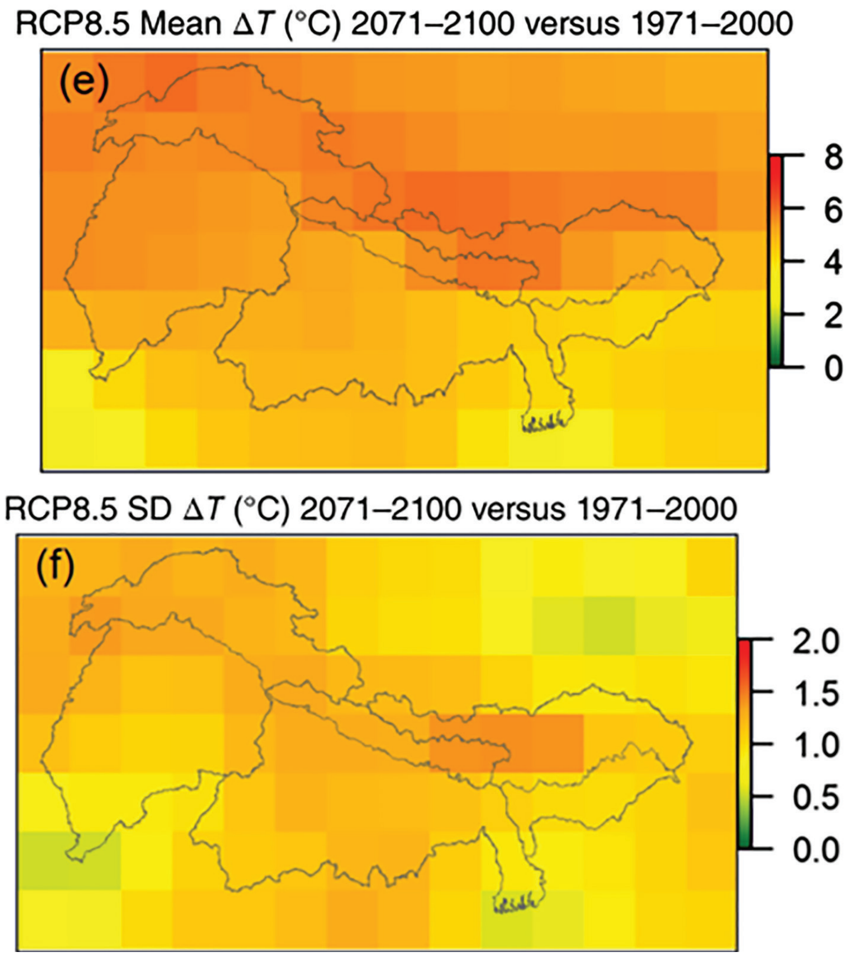


Figure 2: Mean and standard deviation for temperature changes (2071-2100 versus 1971-2000)

agriculture and natural sources of water, is increasingly witnessing variability in the yield and availability of such resources, which is partly contributing to out-migration. On the other hand, unsustainable water extraction for agriculture in the plains of the Upper Ganga Basin might further aggravate water availability in the medium term.

- **Migration is varied with out-migration prominent in most hill-states**

There are considerable out-migration trends from the high and mid-elevation regions in some Mountain States. In our study areas, drivers of migration have been observed to be multi-fold, including lack of access to basic services like water, health and education, as well as alternative livelihood opportunities. Climate induced migration although not significant is largely observed to be resulting in permanent displacement or dislocation of population.

- **Access to Water in Mountains and Drying up of springs**

While rivers flow through mountains and they are seemingly rich in the availability of water resources, access to water in many areas in mountain systems is a challenge. The mid-elevation reaches of the mountains suffer from challenges related to water scarcity even for drinking purposes given their dependency on springs which has both natural and induced variability in its flows, and many-a-times leading to drying-up of these sources over time. Causal factors include earthquakes, source depletion and obstruction, deforestation and unplanned plantation besides climatic factors.

- **Cities are melting. Relentless heatwaves have been battering the urban populace**

HI-AWARE is trying to understand heat stress patterns in neighbourhoods across three cities in Bangladesh, India and Pakistan. In New Delhi – India, large spatial variations in indoor and outdoor temperatures were identified across neighbourhoods through our research. Better urban planning can lead to significant improvement in temperatures and can alleviate communities' vulnerabilities. Active cooling can achieve necessary indoor temperature reductions, but is energy intensive, and is out of reach for the poor households.

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DELTAIC HOTSPOTS IN INDIA

Deltas, Vulnerability and Climate Change: Migration and Adaptation (DECCMA)

Hotspot Description

Large fertile tracts of land at low elevation make deltas vulnerable to sea-level rise and other climate change effects. Deltas have some of the highest population densities in the world: in total with 500 million, often poor, residents. The adaptive strategies available to delta residents may not be adequate to cope with pervasive, systematic, or surprise changes associated with climate change. Hence large movements of deltaic people from these hotspots are often projected under climate change. In India, two such deltas have been studied under DECCMA.

The Indian part of study area in the GBM delta is called the Indian Bengal Delta, also known as Indian Sundarban Delta. The total study area is 14054 sq.km and comprises of 2 administrative districts, North 24 and South 24 Parganas with a population around 18 million. The IBD presents a complex ecosystem formed by an intricate network of tidal waterways, mudflats, and small islands of salt-tolerant mangrove forests which is also a habitat of the Royal Bengal Tiger. Tropical cyclones and floods/waterlogging are the dominant climate induced biophysical hazards and a considerable amount of land erosion is also prevalent along the long coast and islands. The Mahanadi Delta (MD) has been formed by the sedimentation of three major rivers - Mahanadi, Brahmani and Baitarini. The delta has a coastline of around 200 km, stretching from Chilika in the south to Dhamra River in the north. Five districts namely Bhadrak, Kendrapara, Jagatsinghpur, Khordha, and Puri with nearly 8 million of population have been selected site for the Mahanadi delta with an area of 13,109 Km2 considering the 5 meter contour. Monsoon flooding, tropical cyclones and erosion are the dominant climate induced biophysical hazards for this delta.

Where are we working?

DECCMA is working on all size of deltas. In India, the study sites are the Indian Bengal Delta (Indian part of the GBM delta) and the Mahanadi Delta (Fig. 1 and Fig 2).

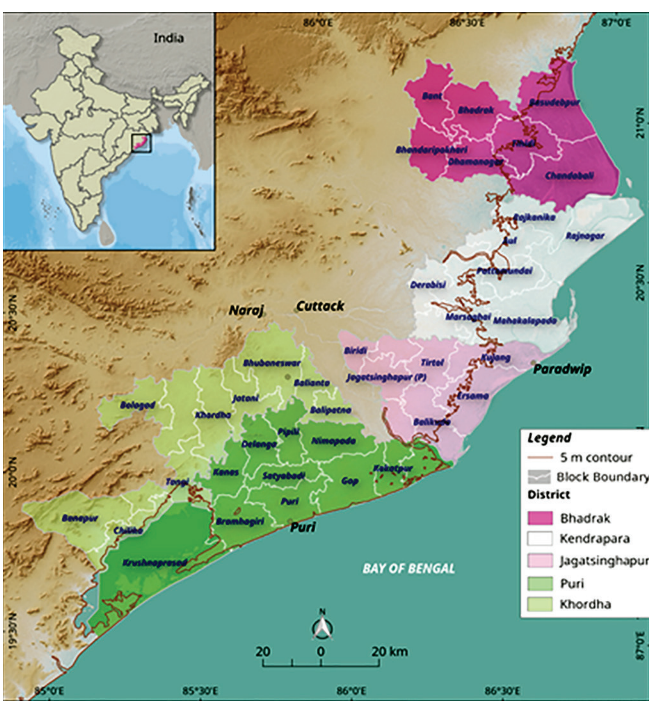

Figure 1: Mahanadi Delta

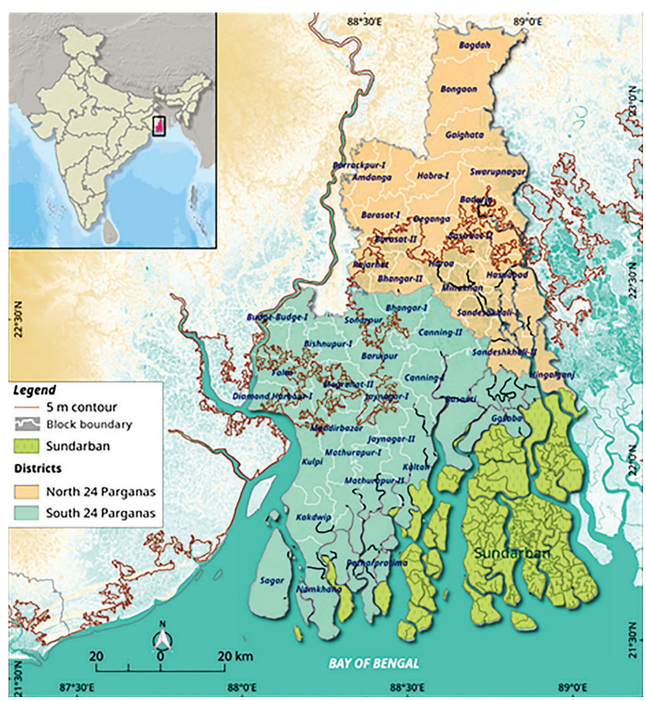

Figure 2: Indian Bengal Delta

What are we working towards?

DECCMA aims to evaluate the effectiveness of adaptation options, to assess migration as an adaptation in deltaic environments under a changing climate, and to deliver policy support to create conditions for sustainable gender-sensitive adaptation.

What have we found?

- **Environmental Hazards in the deltas**

  Coastal blocks are exposed to climatic hazards like flood, cyclone, erosion, storm surge. Flooding is frequent in Mahanadi and magnitude of coastal erosion is high in IBD among other hazards.

  Biophysical and socio-economic factors were categorised into hazard, sensitivity and adaptive capacity to determine levels of risk. Based on the risk score, the sub-districts were ranked and hotspots were identified.

Monsoon floods and cyclones are the main hazards in the Mahanadi delta. While flooding is limited to smaller areas, cyclones affect wider areas. Erosion is more dominant across the lower reach of the delta. Districts have experienced an increase in flood disaster risk over the last three to four decades, with a consequential increase in economic losses reported. Village level multi hazards map is shown in Figure 3.

Both flooding and cyclonic Hazards are dominant in the delta but flooding is limited to smaller areas while the spread of cyclones is over wider areas. Erosion is more dominant along the coastal part of IBD. Village level multi hazard maps for IBD is shown in Figure 4.

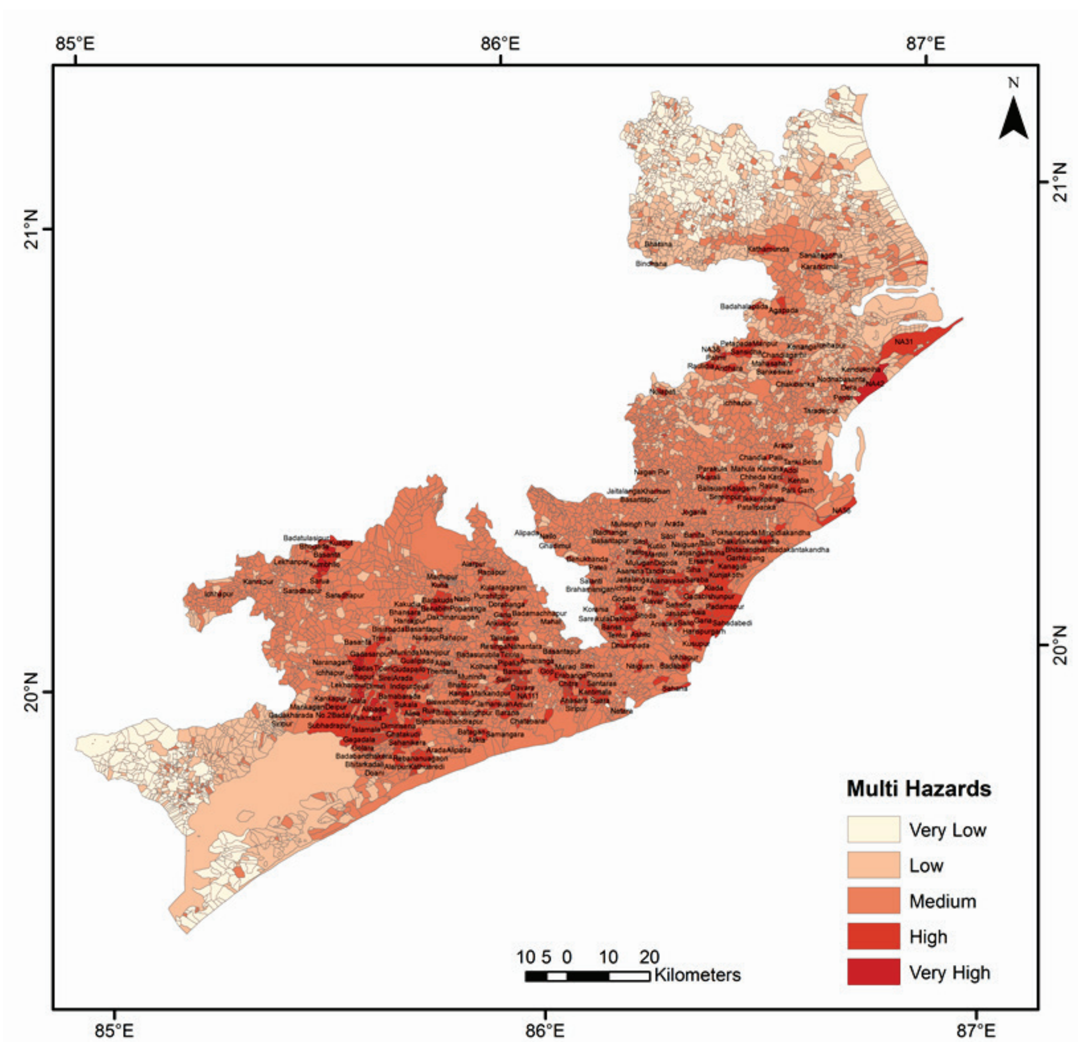

Figure 3: Multi Hazards Map Mahanadi Delta

- **Environmental Hazards affect Agriculture**

  Land cover mapping for 2011-12 for both the deltas showed agriculture as the most prominent category of land cover, occupying more than 50% of the land under single, double or triple crop type. This indicates that the delta economy is primarily agrarian in nature.

  Agriculture is the most affected economy among others due to these hazards. Flood and high salinity are the main hazards, which have impacted agriculture.

- **Effective and equitable adaptation options considering the hazards and risk hotspots are –**

  > Concrete housing development aimed to minimize the impact of cyclones,

  > Agricultural adaptation and methodological improvement,

  > Improvement /construction of shelterbelt to prevent coastal erosion and storm surge inundation.

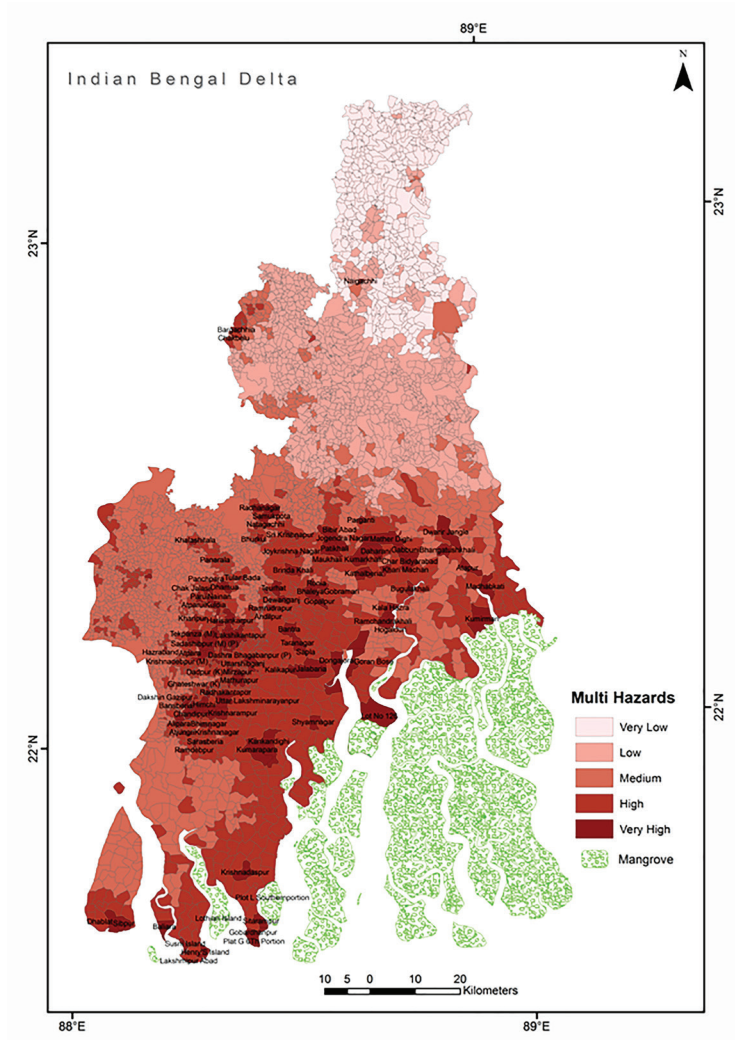

Figure 4: MultiHazards Map Indian Bengal Delta

Both IBD and MD are facing environmental hazards like flood (riverine, fluvial and coastal), cyclone, storm surge and land erosion. Flooding is frequent in Mahanadi and the magnitude of coastal erosion is high in IBD among other hazards. Dhamnagar, Tihidi, Chandabali, Marshaghai, Bhadrak, Ersama, Balikuda blocks are bio-physically and socio-economically at very high risk as compared to the other blocks in Mahanadi delta, whereas in Indian Bengal Delta, the hotspot blocks are Gosaba, Sandeshkhali-II, Patharpratima, Hingalganj, Sagar, Basanti, and Kultali.

These blocks need to adapt to the adverse impacts of climate change. Better housing plans can reduce the impact of cyclonic winds, better road connectivity can improve emergency evacuation. Building and strengthening of embankment can reduce the coastal flooding. Creating option for alternative livelihoods that are less sensitive to climate change can reduce risk to climate change to a greater extent.

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SEMI-ARID HOTSPOTS IN INDIA

Adaptation at Scale in Semi-Arid Regions (ASSAR)

Hotspot Description

The semi-arid regions of India are characterized by dynamic climatic and non-climatic risk profiles. These risks, separately and in interaction, make people and systems living in these regions highly vulnerable, serving as a critical barrier to effective, widespread and sustained adaptation.

Where are we working?

The ASSAR-India study areas are regionally spread , viz. Bangalore sub-region in Karnataka (which includes Kolar and Gulbarga districts in Karnataka), Moyar-Bhavani sub-region in Tamil Nadu and the Sanganmer sub-region in Maharashtra

What are we working towards?

ASSAR's overarching research objective is to use insights from multiple-scale, interdisciplinary research to improve the understanding of barriers, enablers and limits to effective, sustained and widespread adaptation, to the 2030s. Using interdisciplinary approaches and within the ambits of building a closer understanding of the hot-spot of semi-arid regions in India and drawing from both research and practice, we attempt to characterize the nature and structure of biophysical vulnerability.

What have we found?

Using rigorous assessment methodologies, our research findings are reported below:

- **Indian semi-arid regions have experienced an increasing temperature trend.**

Statistically significant annual warming and drying trends are observed over most parts of semi-arid region in India at 95% confidence level, during 1951-2005. Initial assessment indicate a significant increase in annual mean temperature and precipitation by the end of the 21st century over the SARs (future changes are computed w.r.t the base period 1976-2005).

Statistically significant decline of southwest (JJAS) monsoon in SARs of NW and Central India has been observed; these trends are amplified in the sub-humid regions to the east of the SARs; whereas parts of south India are seeing an increase in the amount of JJAS rainfall, however the amount of rainfall received during the northeast (OND) monsoon is declining. This is influencing crop choice and impacting crop cycles, straining livelihoods in the region.

- **Expansion of semi-arid region in India**

A 4% expansion in the area of semi-arid region is observed during recent decades.

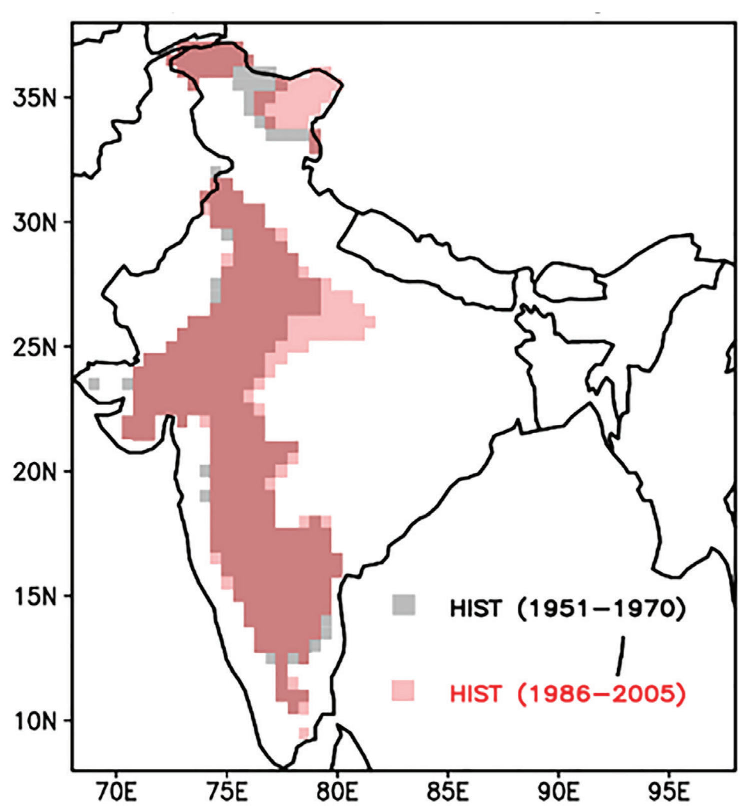

Figure 1: Observed expansion of semi-arid region in India

- **Uncoupling of Vegetation Greenness from climate in the semi-arid regions (SARs) of India:**

Significant greening of vegetation is observed across pockets within the SARs. This is despite the declining rainfall observed over 1951-2007 and is likely linked to a growing dependence on groundwater for crop, drawing concerns towards water security issues.

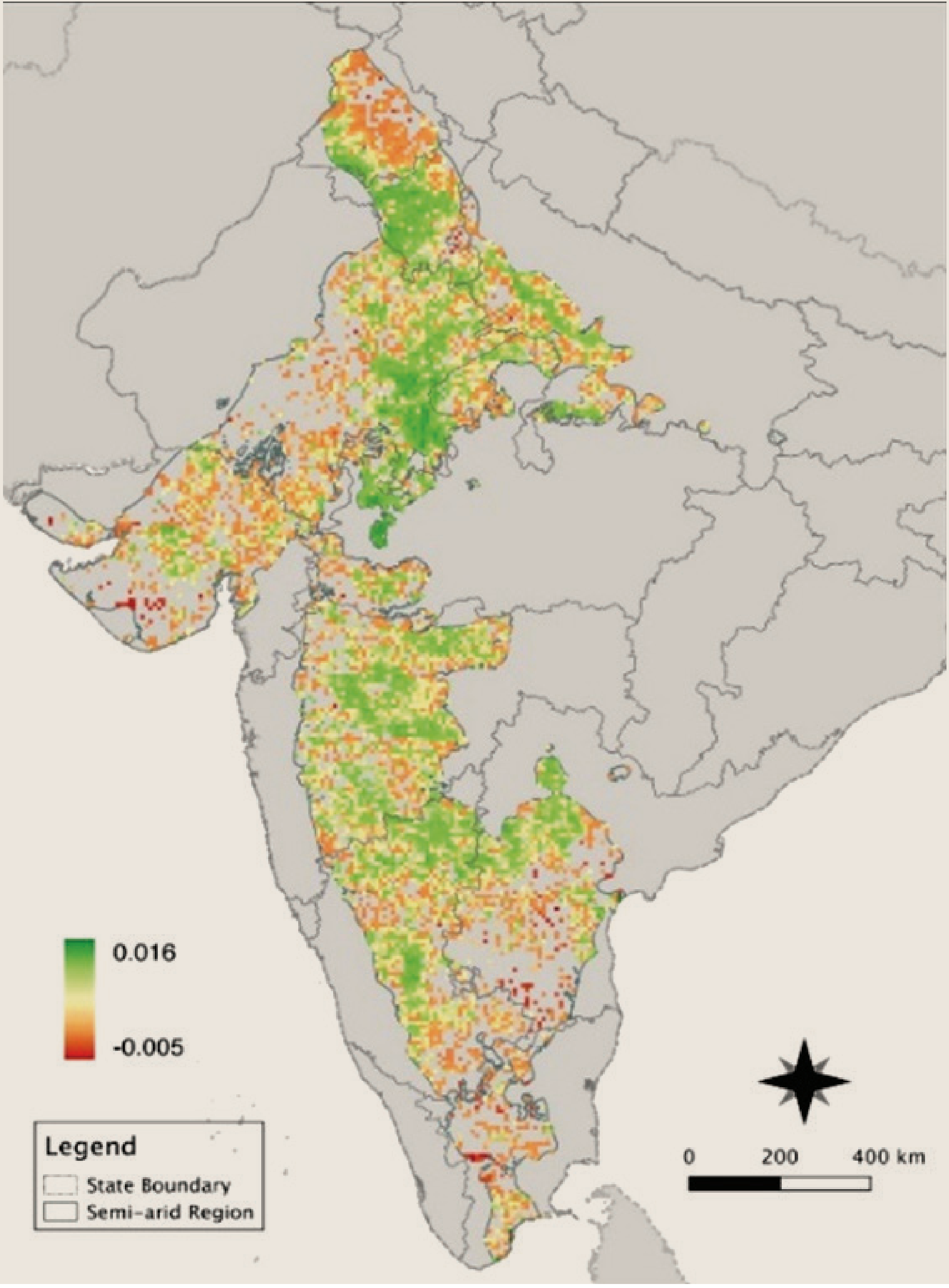

Figure 2: Trends in vegetation greenness (NDVI units/year) from 1982-2015 in the semi-arid region (SAR) of India. Coloured cells indicate areas where the trend is statistically significant at the 95% level

Regionally, some of our prominent analysis has focused on understanding land use and vegetation dynamics, being summarised below:

- **In the Sangamner semi-arid sub-region, fallow lands and wastelands are being converted into cultivated land but crop land is biased towards plantations (pomegranate and sugarcane).**

The spatio-temporal Land Use Land Cover

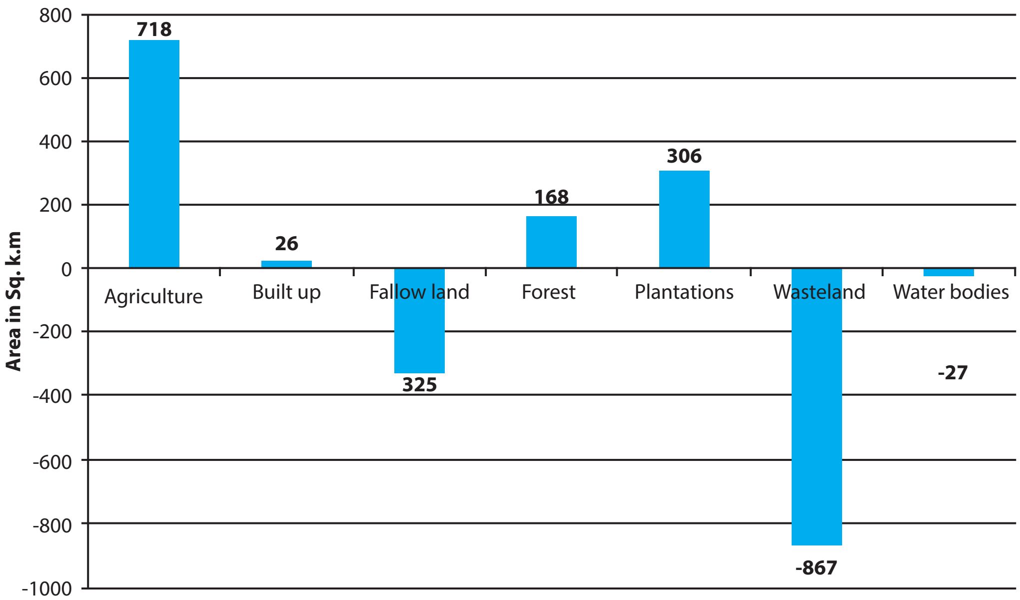

Figure 3: Land-use-Land-cover changes in Mula-Pravara region (1991-2016)

(LULC) changes within the Mula-Pravara region (basin cutting across the Sangamner region) indicates an increase of agriculture land and horticulture plantation area by about 98% and 1601% respectively, between 1991-2016 (Figure 4). At the same time, a decline in un-culturable and culturable wasteland (UCW) category by 34.6% and fallow lands by 60.5% was also noted. Growing dependence on irrigation sources has been attributed as the key drivers for this change, with impacts on the groundwater level and therefore posing major challenges for groundwater management.

- **Extensive coverage of extreme Groundwater Vulnerability identified in Sangamner region (Thomas & Duraisamy 2016)**

In order to contemplate site-specific differences in people's vulnerability to groundwater availability in aquifers, a combination of physical hydrogeological mapping, aquifer -testing and remote-sensing mapping techniques were used to classify the villages in Sangamner region into four vulnerability classes, viz. Extreme (52%), high (35%), moderate (7%) and low(6%) (Figure 5) . The vulnerability extends further to other adjoining villages characterised by the same underlying basaltic aquifers. The dimensions of extreme ground water vulnerability may have serious implications for water security, particularly for agriculture and for the successful implementation of any drought-proofing schemes, in the region. The existing variability in aquifer characteristics (below ground), coupled with unsustainable resource use patterns (on ground) and changing

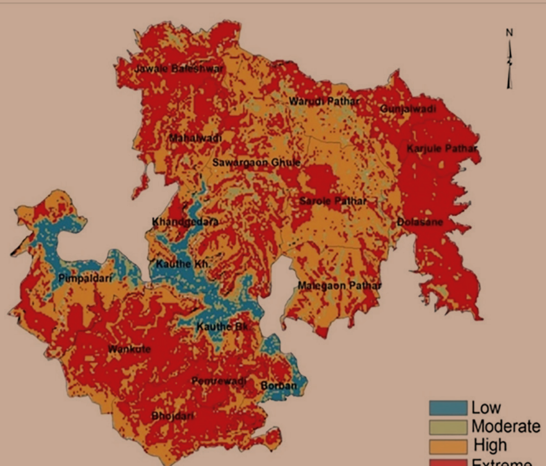

Figure 4: : Groundwater Vulnerability classes in 17 villages of Sangamner and Akole, Ahmednagar District.

rainfall regimes (climatic externalities) are barriers that have the potential to seriously cripple agrarian livelihoods in the region. Current practices of groundwater exploitation and use (pumping excessively; lifting groundwater onto surface farm ponds; drilling new and deeper wells) has put further stress on the base water flows and has dramatically reduced water availability.

- **In the Moyar-Bhavani (M-B) semi-arid sub region of Tamil Nadu, we find changes in vegetation greenness**

Significant greening of vegetation is observed across pockets within the M-B SAR. This is despite the declining rainfall observed over 1951-2007 and is likely linked to a growing dependence on groundwater for crop. In agricultural areas (esp. along the Bhavani River), these reflect agricultural intensification, whereas in forested regions (esp. along the Moyar River) these reflect an increase in invasive species, identified as Prosopis. These trends have serious implications for sustaining natural resource based livelihoods in the region.

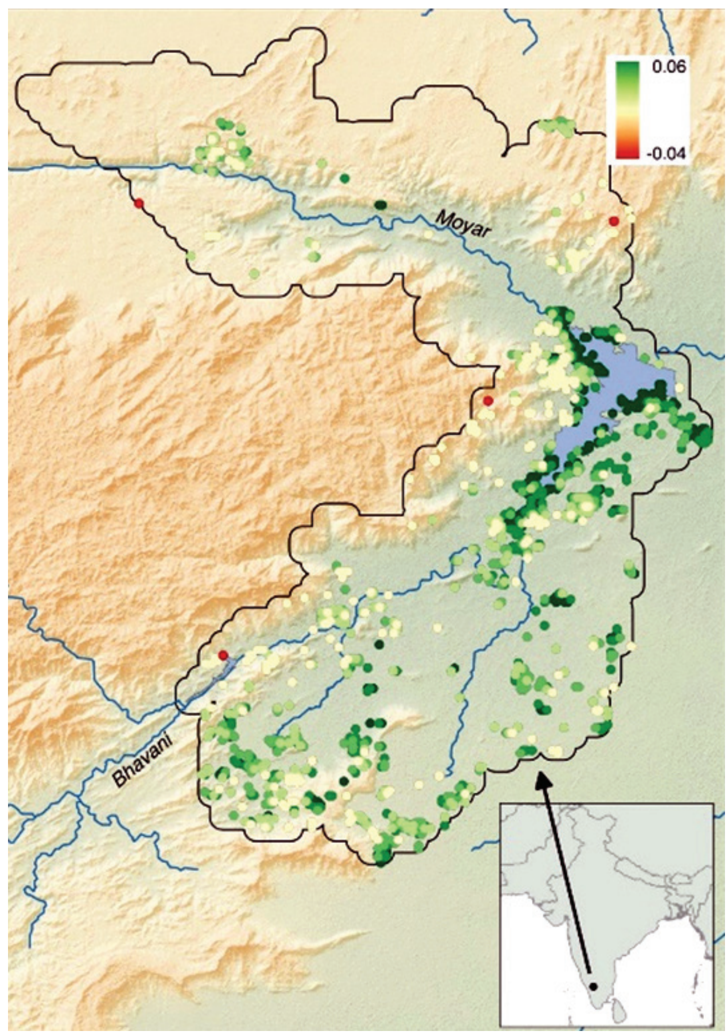

Figure 5: Change in Vegetative Greenness in Moyar-Bhavani Region

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[1] Extreme: Water is being tapped from deeper confining aquifers and presence of massive basaltic units limiting groundwater recharge;
High- Excessive pumping of wells and a gradual shift to groundwater exploration of deeper confined aquifers;
Moderate: Presence of dykes, fractures, weathered rocks and drainage lines that provide moderate water;
Low: Presence of thick alluvial aquifers that have higher capacity to store and transmit groundwater;

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DISCUSSION

Our research indicates and reemphasises that social vulnerability maybe compounded by changing biophysical and climatic conditions, indicating likely situations of widespread vulnerability. We also observe that biophysical conditions are changing distinctly and influencing livelihood regimes. Hence, it becomes imperative to address underlying socioeconomic and biophysical conditions that drives vulnerabilities, but in the context of changing livelihood and agricultural practises. This also has strong complementarity with the targets under Sustainable Development Goals and resonates with the Hotspot Approach. The various pieces of research when weaved together present unique findings that on one hand are very location specific and on the other, when synthesised and abstracted, can lead to informing proactive climate planning. These issues will be further discussed in Brief 3 on Adaptation Policy.

IN-COUNTRY CONSORTIA DETAILS:

- Glacier and snowpack dependent river basins – Himalayan Adaptation, Water and Resilience (HI-AWARE) – In Country Lead – The Energy and Resources Institute (TERI) – In country partners – Centre for Ecology, Development and Research (CEDAR), Uttarakhand and The Mountain Institute (TMI), Sikkim
- Deltas – DEltas, Vulnerability & Climate Change: Migration and Adaptation (DECCMA) – Jadavpur University – In Country Lead – In country partners – National Remote Sensing Centre, Hyderabad; Chilika Development Authority, Odisha; Sansristi, Odisha; Centre for Environment and Development, Kolkata
- Semi-arid regions – Adaptation at Scale in Semi-Arid Regions (ASSAR) – In Country Lead – Indian Institute for Human Settlements Bengaluru – In Country Partners – Ashoka Trust for Research in Ecology and the Environment (ATREE), Bengaluru, Watershed Organization Trust (WOTR), Indian Institute of Tropical Meteorology, Pune

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