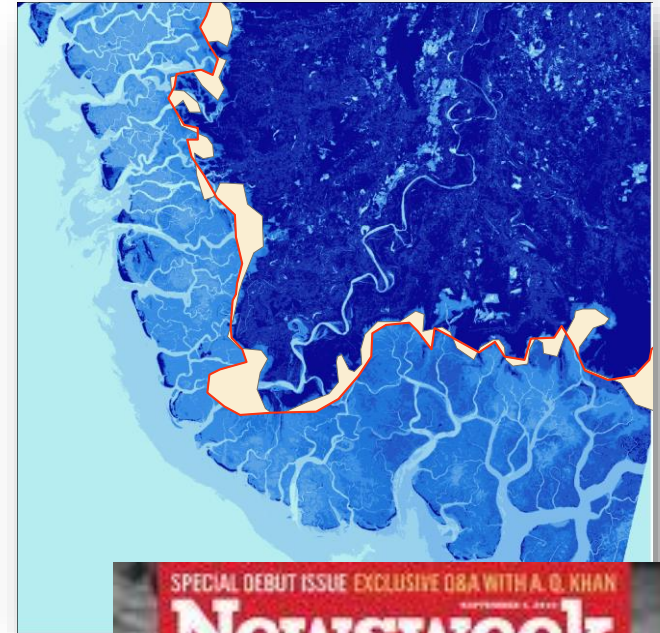




Government of Pakistan  
Ministry of Science and Technology

# Climate Change- Impact on the Coastal Zone & Implications

Samina Kidwai, Ibrahim Zia, Waqar Ahmed  
National Institute of Oceanography, PAKISTAN



# Presentation Scheme

2 parts

PART I                      Brief Introduction  
                                    NATIONAL INSTITUTE OF OCEANOGRAPHY, PAKISTAN

PART 2                      Global Climate Change

Climate Change – Ocean context

NW Indian Ocean, Arabian Sea, Pakistan

Monsoons and weather patterns- predictability or not?

Coastal Erosion

Sea Intrusion

Sea Level Rise

Ocean warming & impacts (ocean processes, productivity & biodiversity)

National Institute of Oceanography- relevant research directions



# NATIONAL INSTITUTE OF OCEANOGRAPHY

## Offices & sub-stations

The National Institute of Oceanography (NIO) was established in June 1982 under the Ministry of Science and Technology (MoST), Government of Pakistan

Main laboratories and office are located at Clifton, Karachi.  
Sub Stations, at Gawdar, Sonmiani and Ghora Bari.

JINNAH STATION - ANTARCTICA



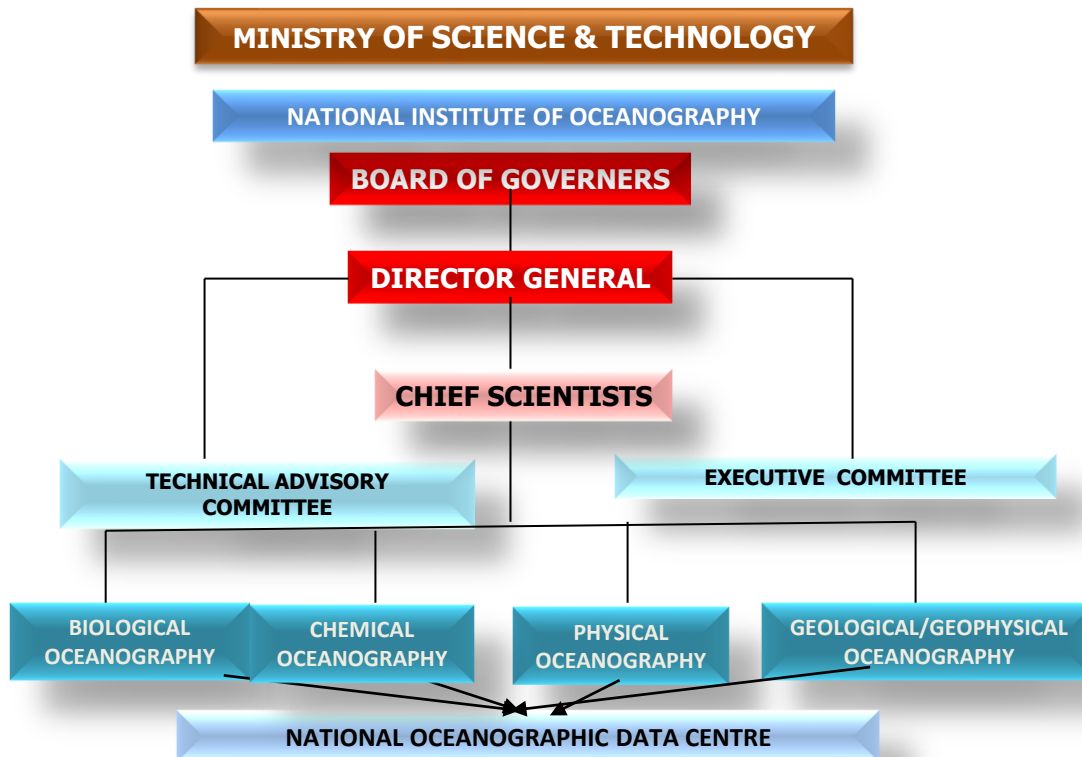
## Mandate/Functions

- a. To undertake mission oriented multi-disciplinary research in Physical, Chemical, Biological and Geological Oceanography in Pakistan's maritime zones;
- b. To undertake oceanographic surveys at the national, international regional and sub-regional levels;
- c. To undertake training programme in various fields of oceanography for the development of indigenous manpower and expertise;
- d. To establish a National Oceanographic Data Centre (NODC), to serve as a national repository for all oceanographic data/information, concerning Pakistan's maritime areas;
- e. To provide necessary advice to the Government and collaborate with other national agencies engaged in maritime activities;
- f. To coordinate and maintain liaison with international organizations/institutes for arranging training or experts services; procurement of specialized instruments and equipment; transfer of marine technology, and development of cooperative research programmes;
- g. To hold Seminars/Workshops/Symposia at national, international, regional and sub-regional levels; and





# Organogram of the Organization



## UNITED NATION'S DECADE OF OCEAN SCIENCE FOR SUSTAINABLE DEVELOPMENT (2021-2030)



### **The Science We Need for the Ocean We Want**

The Decade will provide a "Once in a Lifetime" opportunity for nations to work together to generate the global ocean science needed to support the sustainable development of our shared ocean

# **Goal 14 Conserve and sustainably use the oceans, seas and marine resources for sustainable development**

The Vision 2030 for NIO is

*Conduct world class oceanographic research for uplifting the national image and economy, striving to achieve food-water security and energy self sufficiency, aligned to Pakistan Vision themes*

## PAKISTAN- SUSTAINABLE USE OF THE GLOBAL OCEANS AND PREPAREDNESS FOR THE FUTURE

- **Sustainable Fisheries**
- **Marine Pollution**
- **Climate Related Impacts on the Ocean**
- **Marine Protected Areas (MPAs)**
- **Ocean Renewable Energy**



Cross cutting issues



# Pakistan's coast and offshore

Coast line ~ 1000 km

2 divides- Murray Ridge

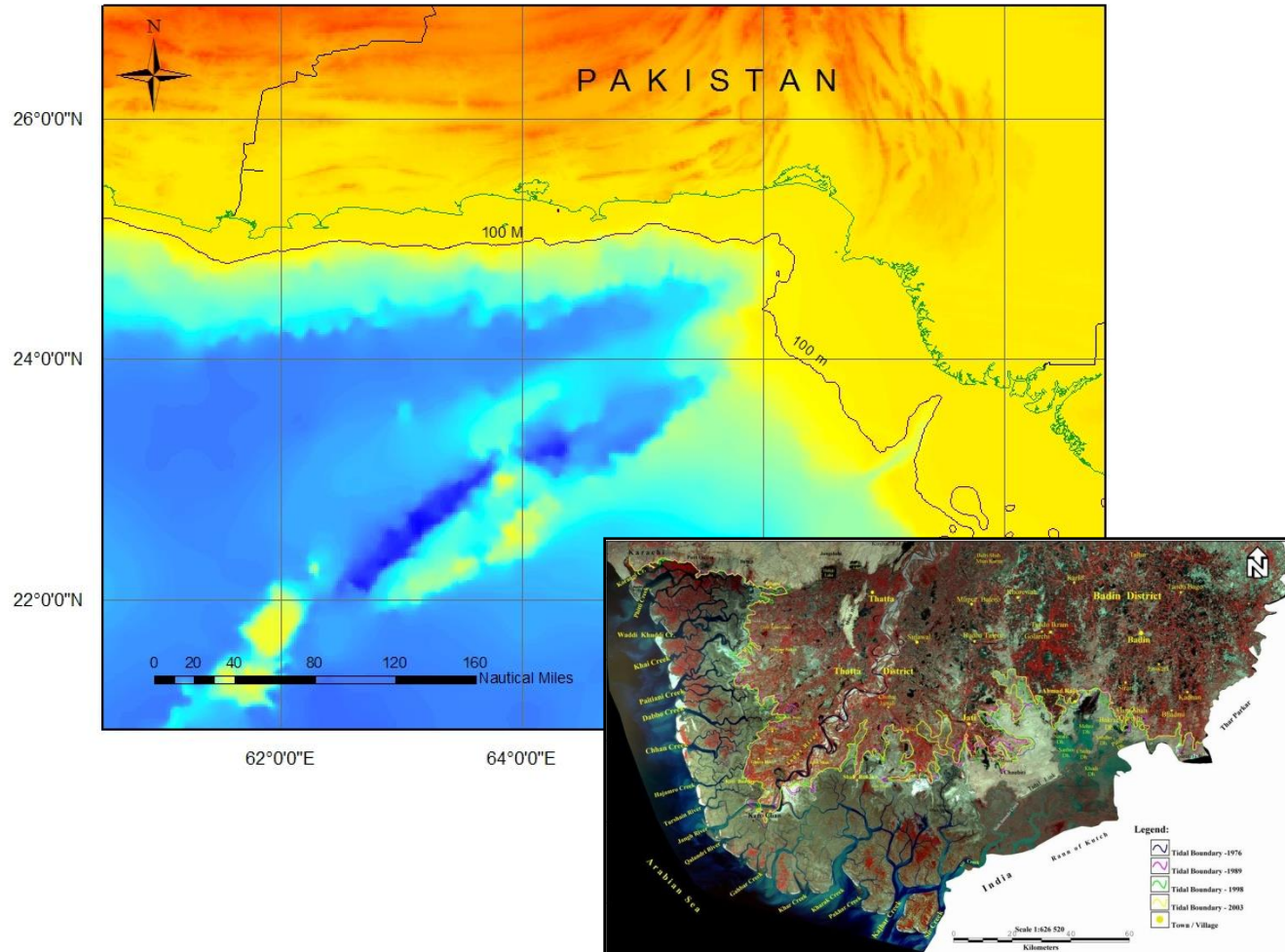
- Makran – narrow CS
- Sindh- broad CS

Indus delta- 1800 sq km

Khoobar creek- main river  
18 main creeks, numerous minor

SWATCH – River Indus enters Sea on the CS

EEZ 240,000 sq. km  
extended CS 290,000 sq. km



# Global Climate Change



# Effects due to Climate Change

Temperature

Precipitation

Sea Level Rise

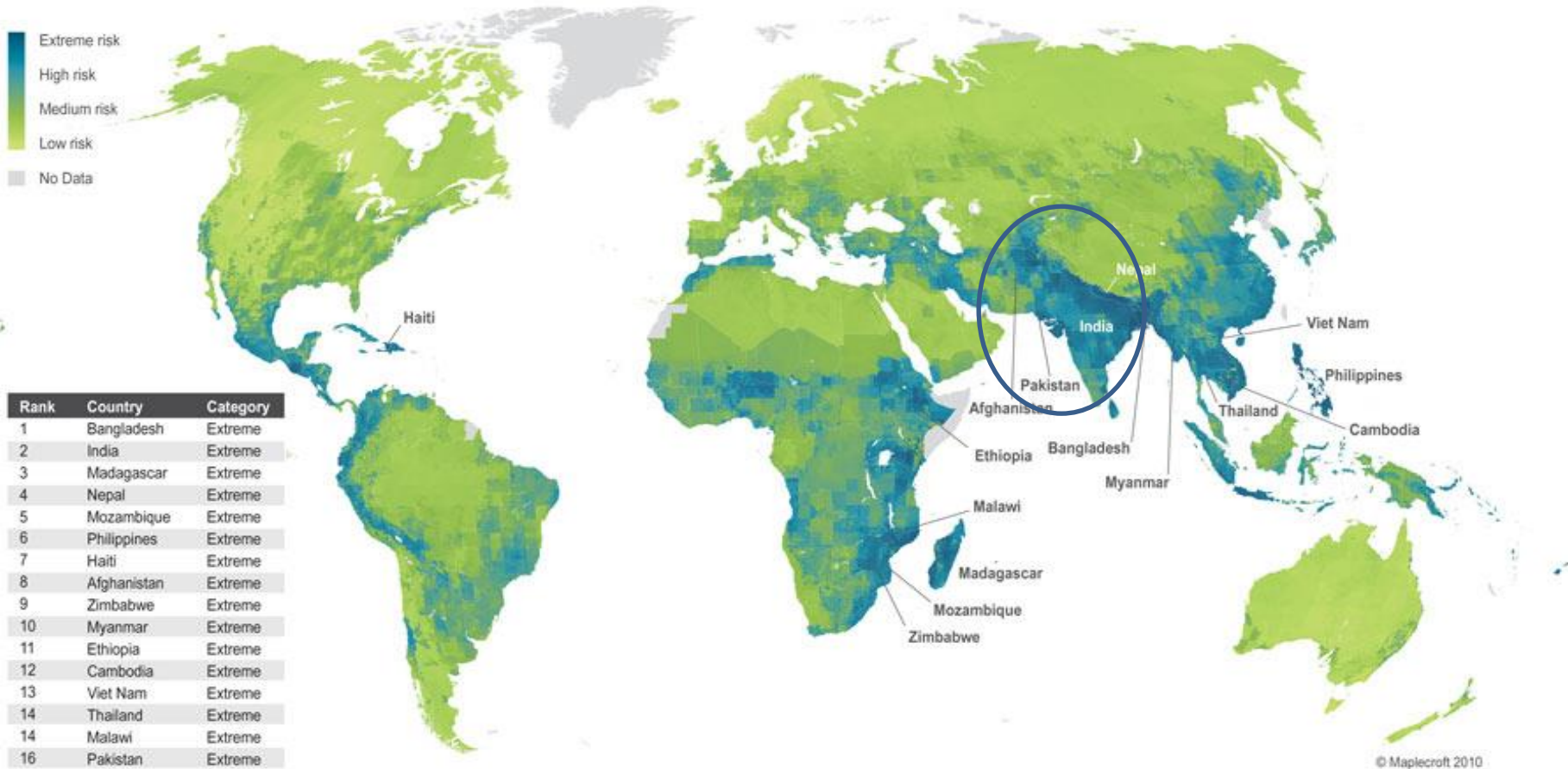
Sectors effected due to Climate Change

- Water Resources
- Agriculture
- Health
- Forests
- Coastal Area
- Species



# Pakistan – where are we ?

## Climate Change Vulnerability Index 2014



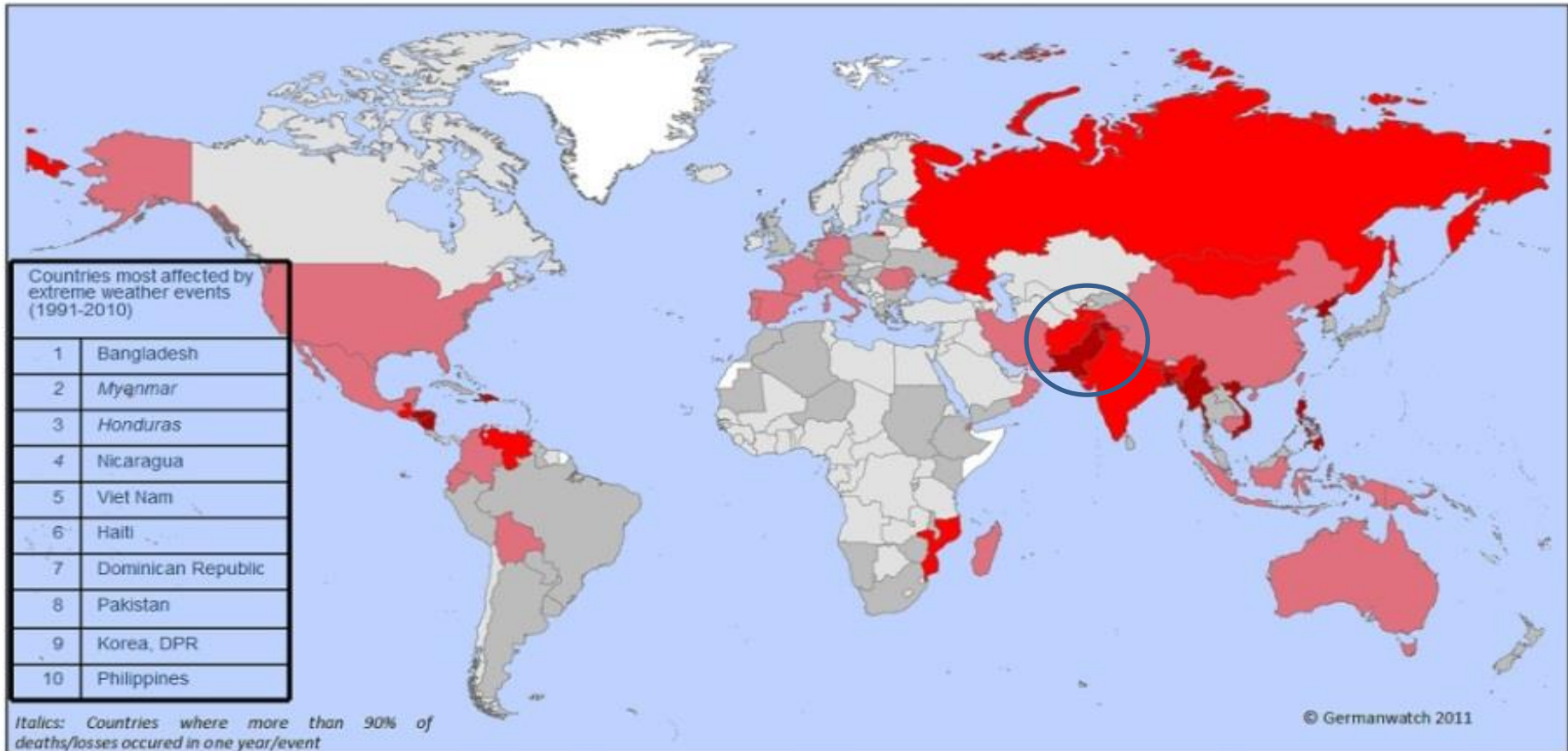


# Pakistan – where are we ?

Global Climate Risk Index 2019 (covering 2000-2019)



Source: Germanwatch and Munich Re NatCatSERVICE



Climate Risk Index: Ranking 2000-2019

# Climate Change- ocean context

Long- term shifts of temperature & weather patterns  
natural human induced

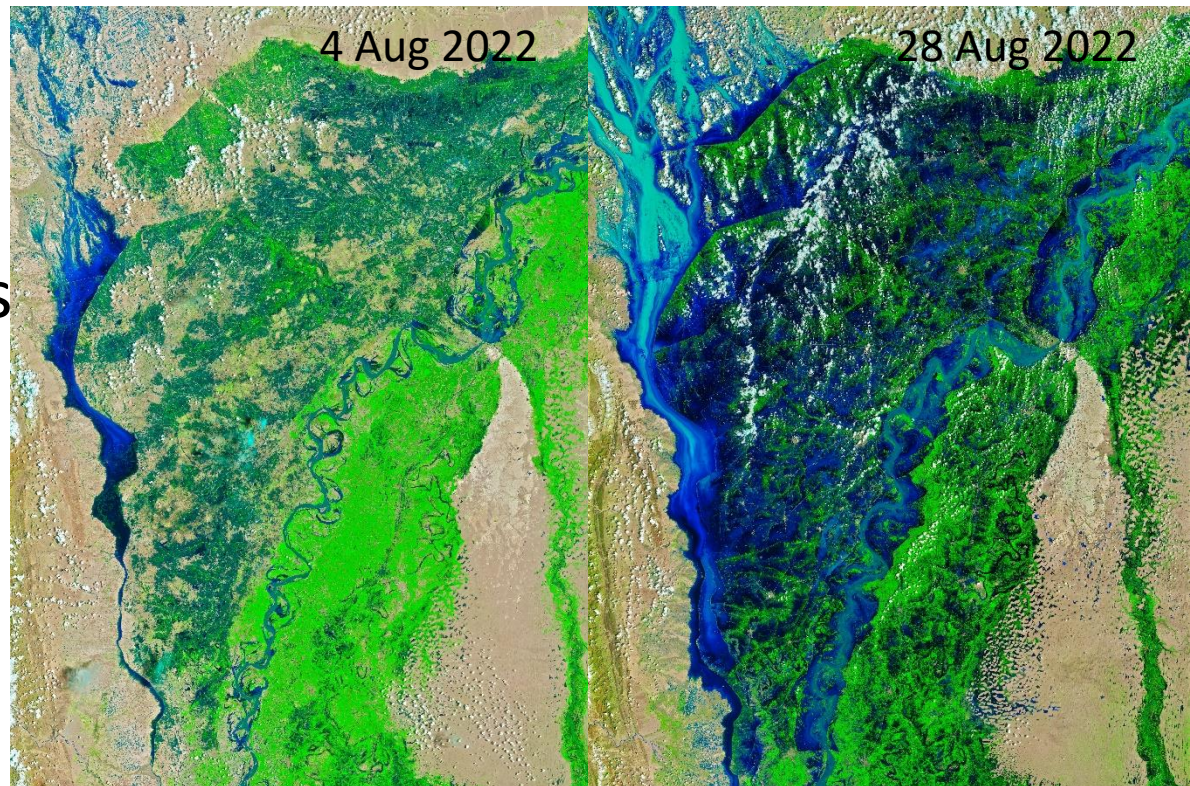
Intense droughts &  
floods

Storms & heat waves

Sea Level Rise

Melting Glaciers

Warming Seas



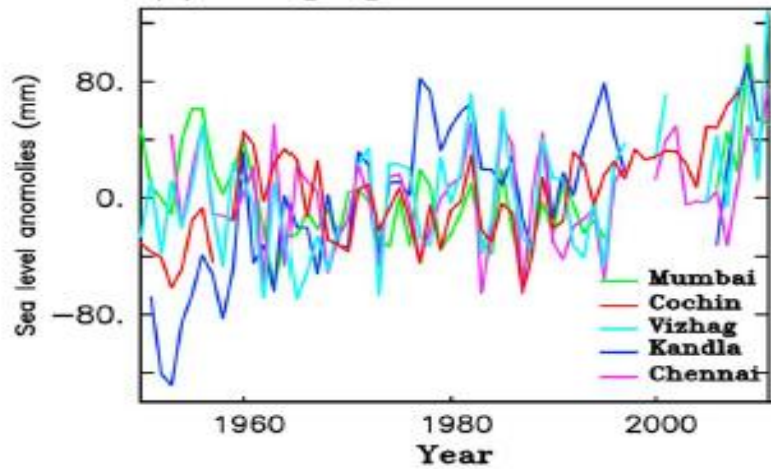
# Impact of Climate Change in Indian Ocean and North Arabian Sea.

Satellite-derived sea level estimates show a rapid increase in North Indian Ocean (north of 5°S) sea level during the last decade (Thompson et al., 2016).

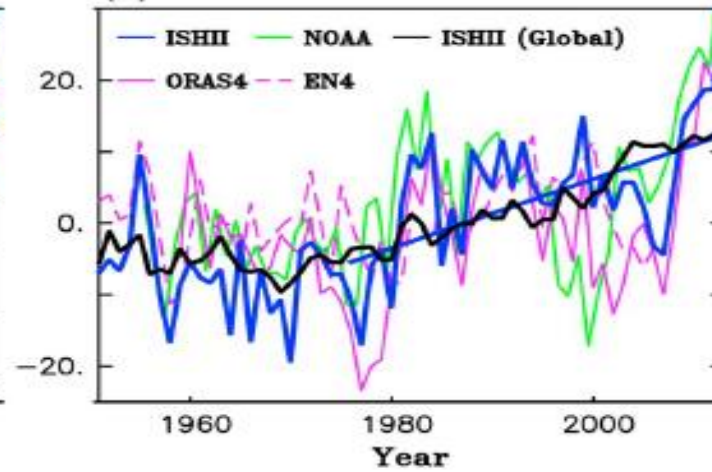
Long-term sea level estimates using tide gauge records show a rate of sea level rise of about 1.06–1.75 mm/yr in the Indian Ocean during 1874–2004 (Unnikrishnan & Shankar, 2007; Unnikrishnan et al., 2006)



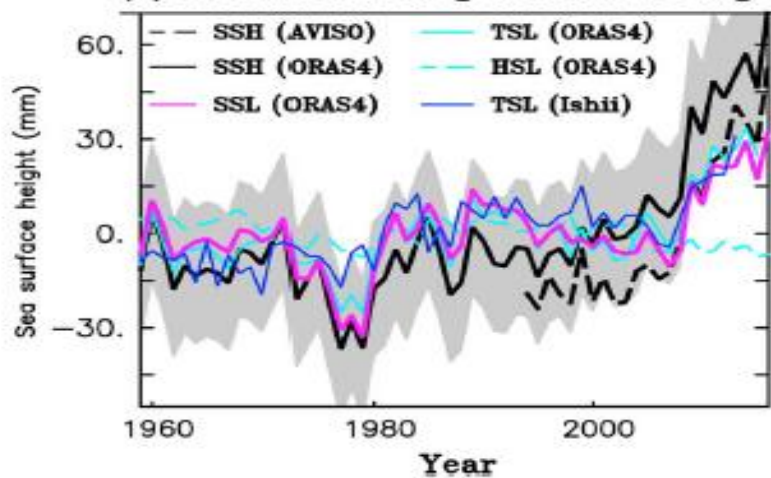
(a) Tide guage



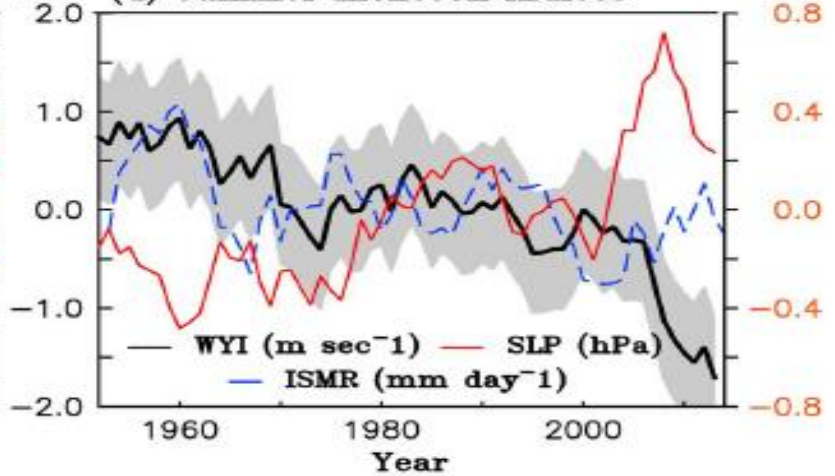
(b) Thermostreic sea level



(c) Sea surface height & steric height



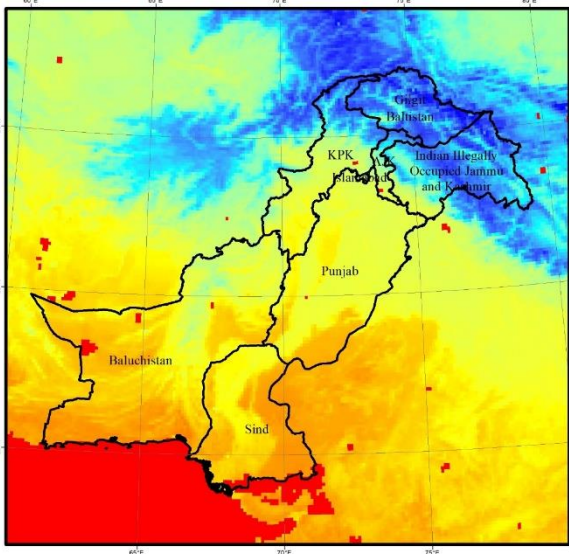
(d) Summer monsoon indices



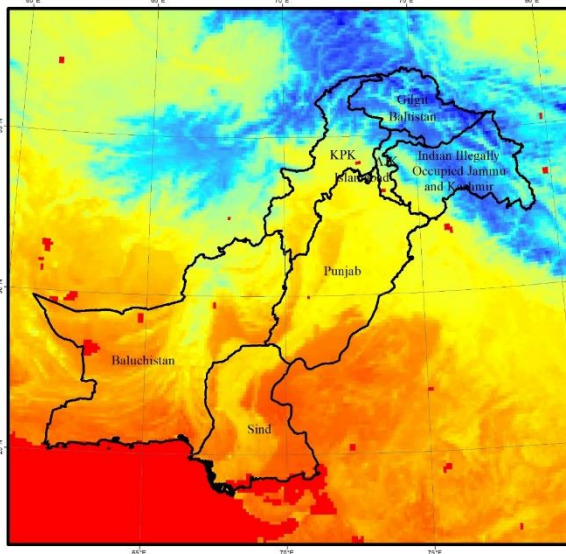


45°C

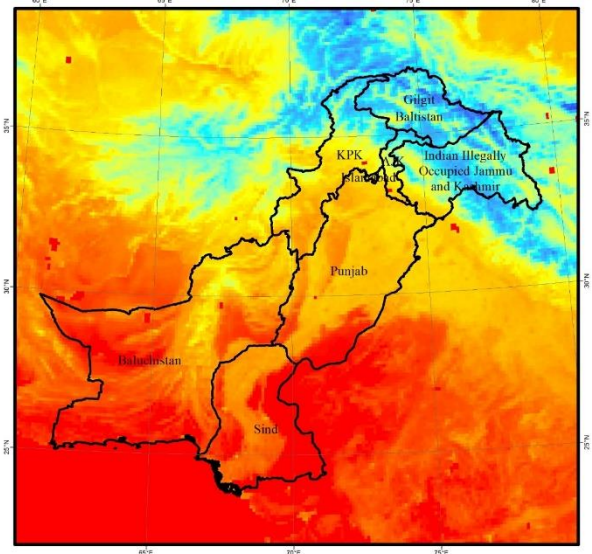
JANUARY



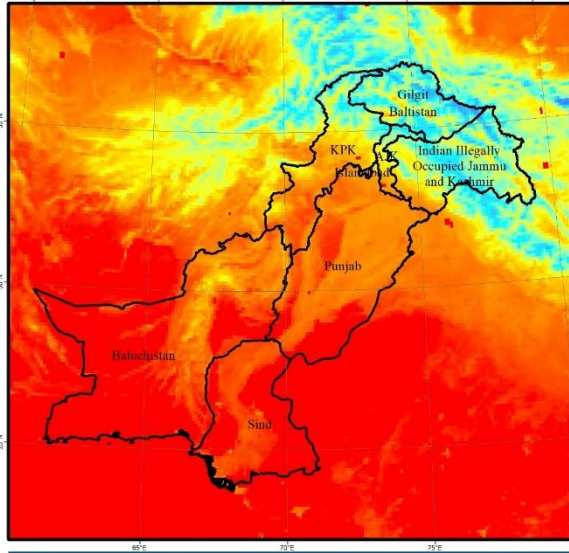
FEBRUARY



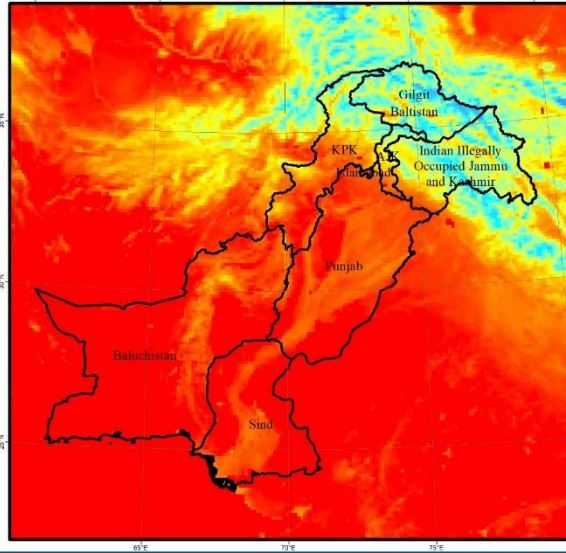
MARCH



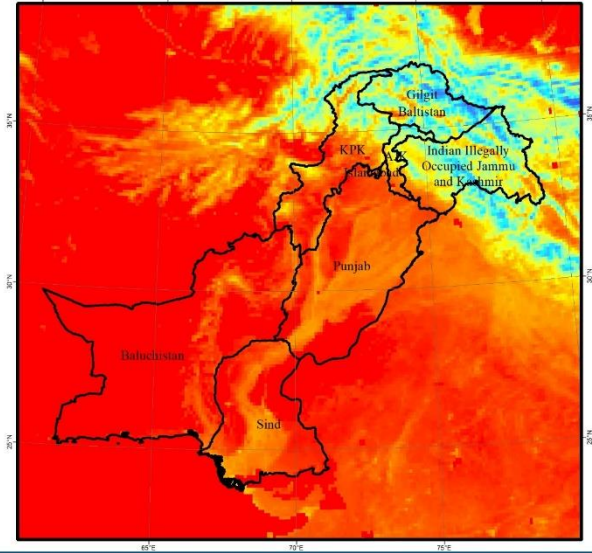
APRIL



MAY



JUNE



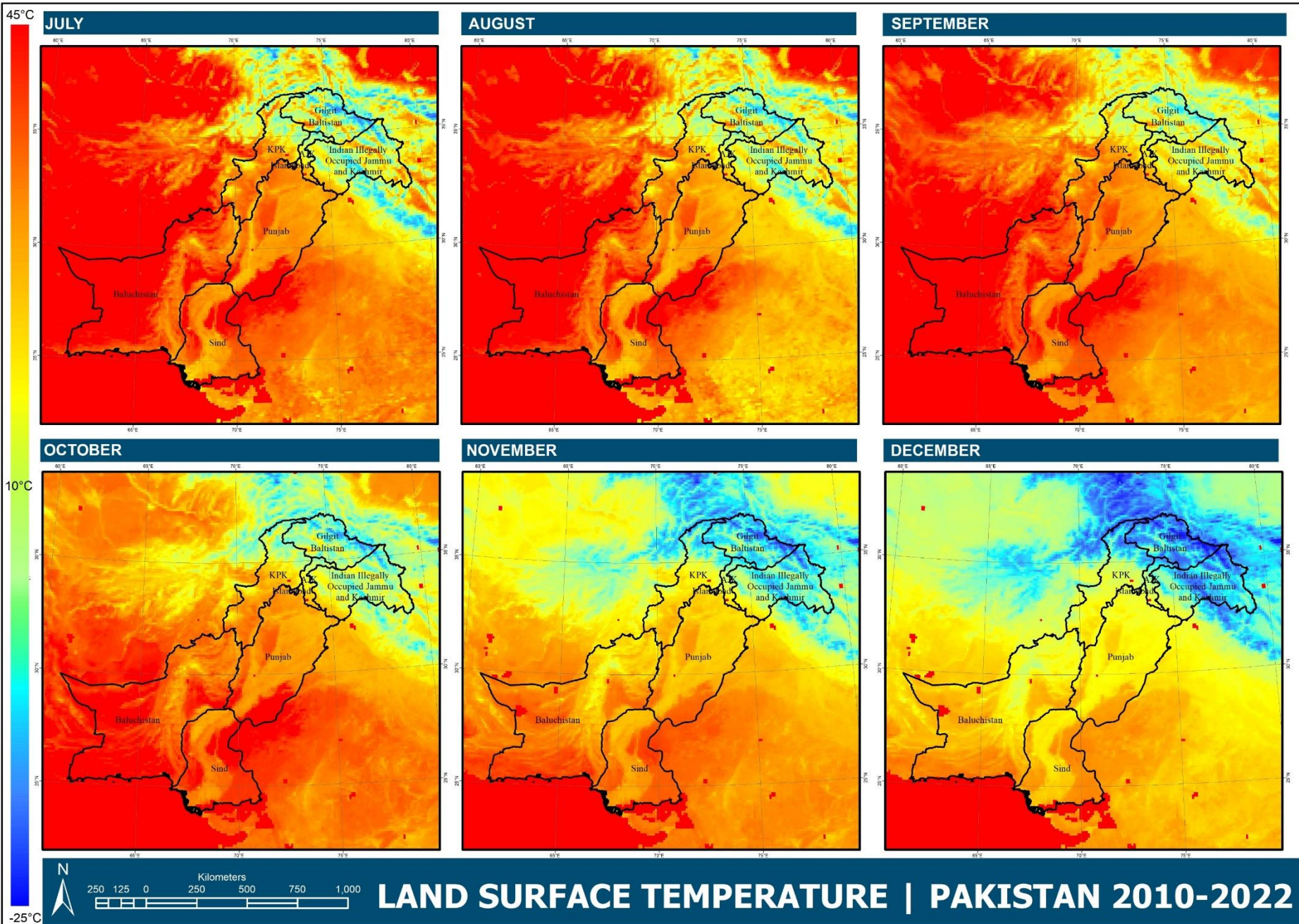
10°C

-25°C



**LAND SURFACE TEMPERATURE | PAKISTAN 2010-2022**





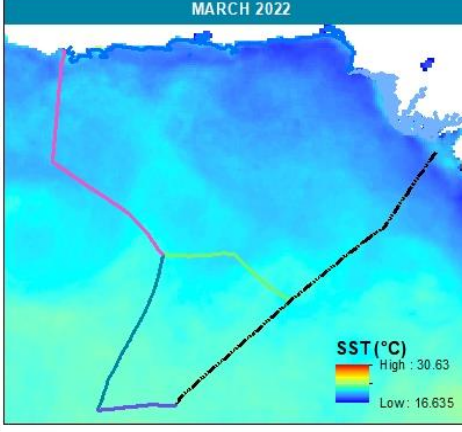
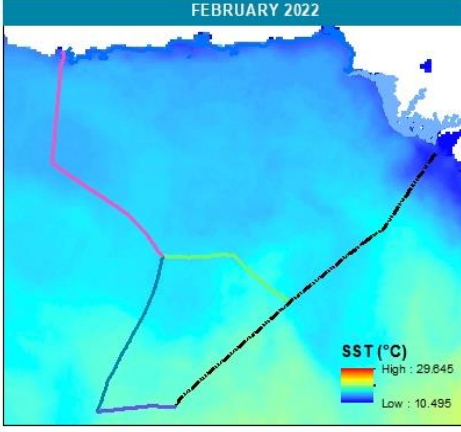
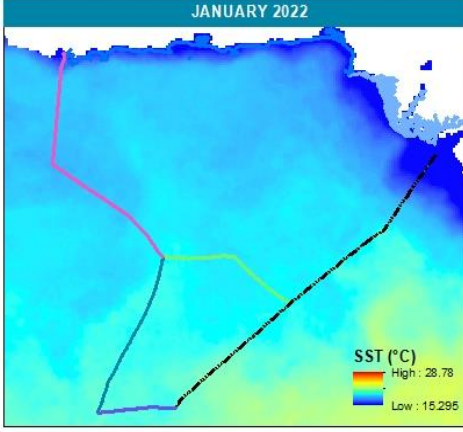
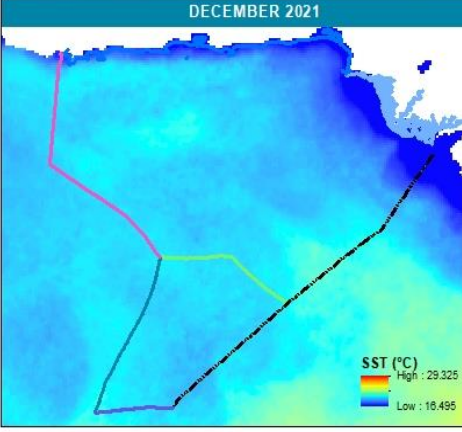
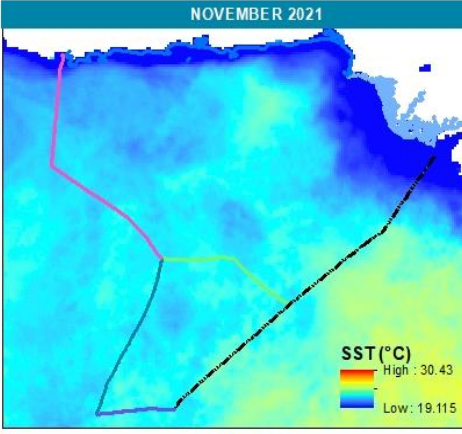
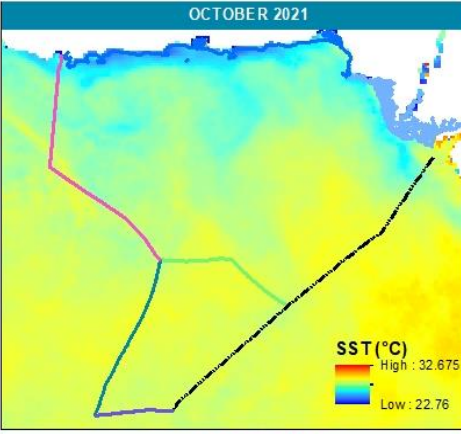
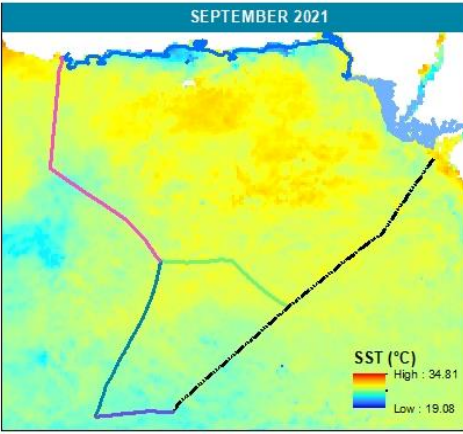
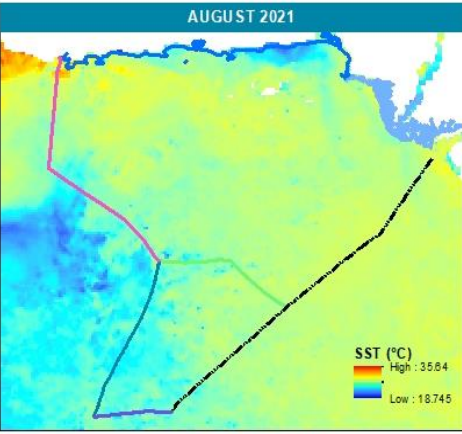
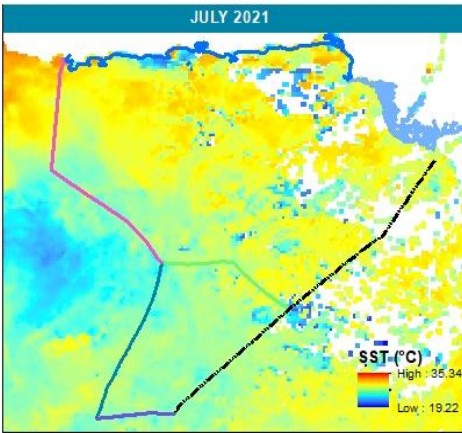
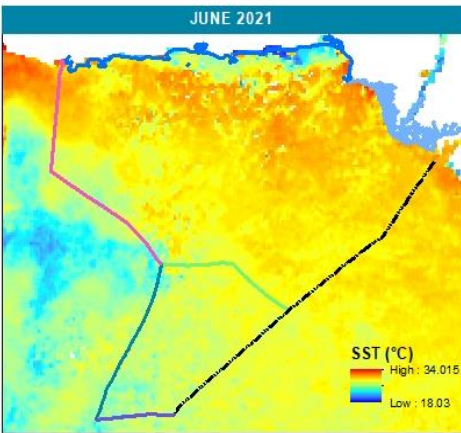
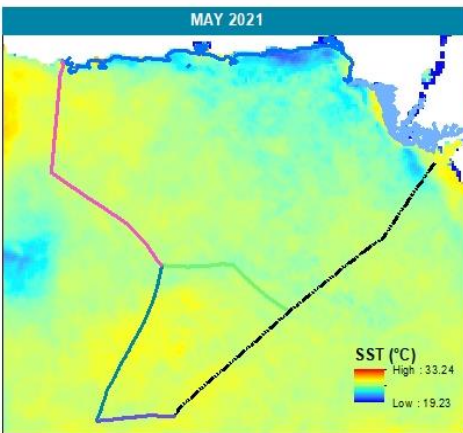
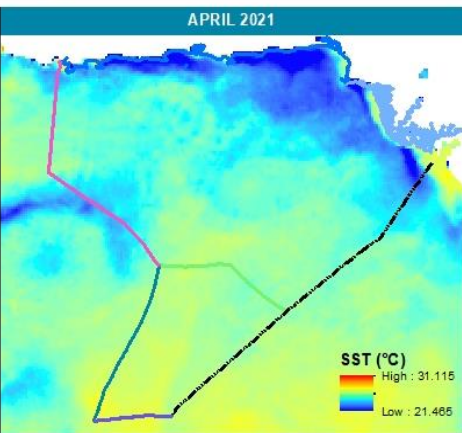
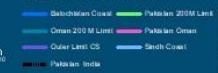




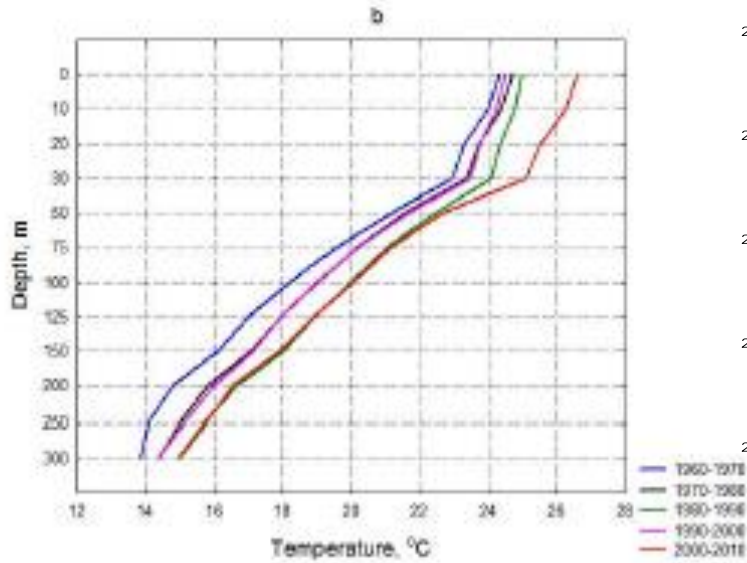
# SEA SURFACE TEMPERATURE (°C) | April 2021 - March 2022



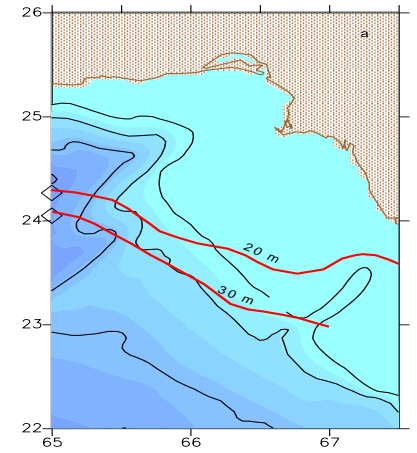
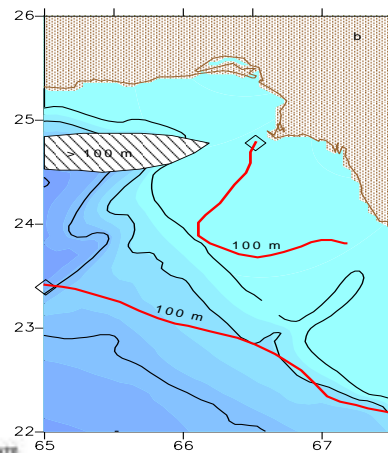
Exclusive Economic Zone



# Summer Temp. Western Arabian Sea (Decadal scale averaging)



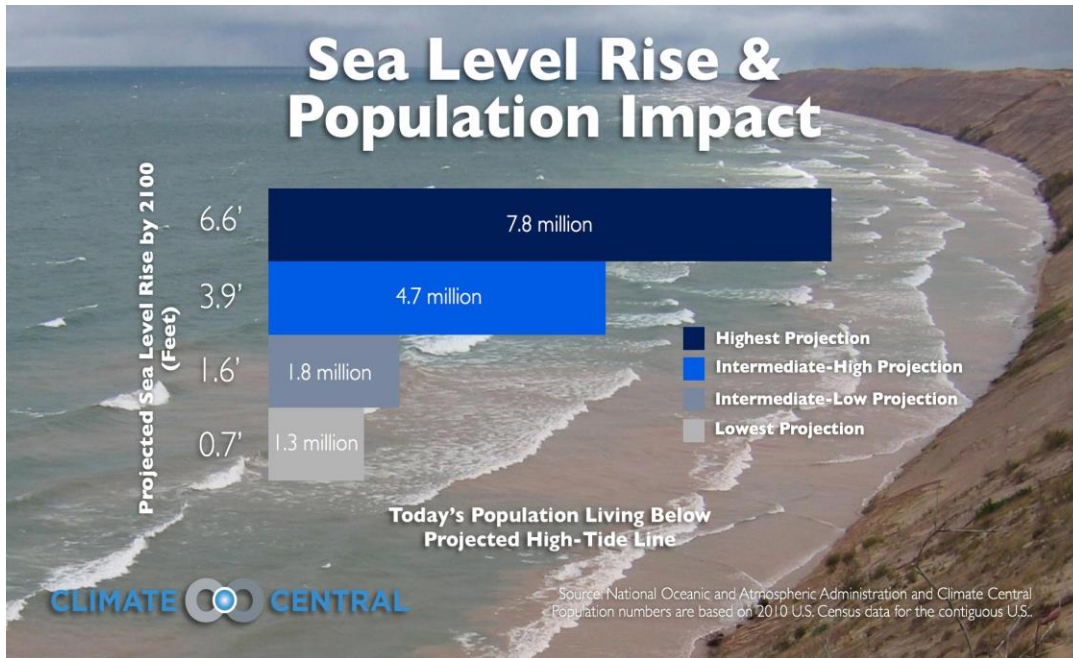
# Mixed Layer Depth (MLD) in the Arabian Sea





# Sea Level Rise in Arabian sea

In South Asia, Pakistan is in a group of countries, which are vulnerable to impact of rising sea level (SLR).



## Sea Level

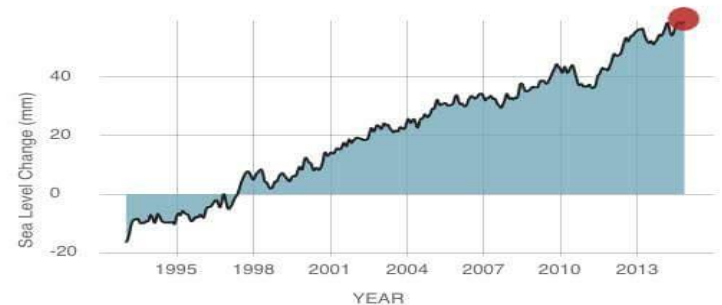
November 2014: **59.5 mm**

SATELLITE DATA: 1993-PRESENT

Data source: Satellite sea level observations. Credit: NASA Goddard Space Flight Center

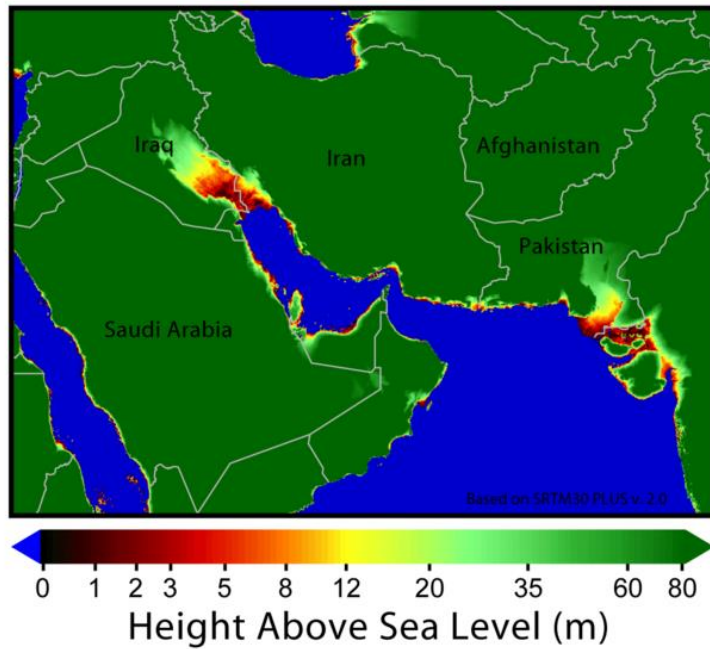
RATE OF CHANGE

↑ **3.18**  
mm per year

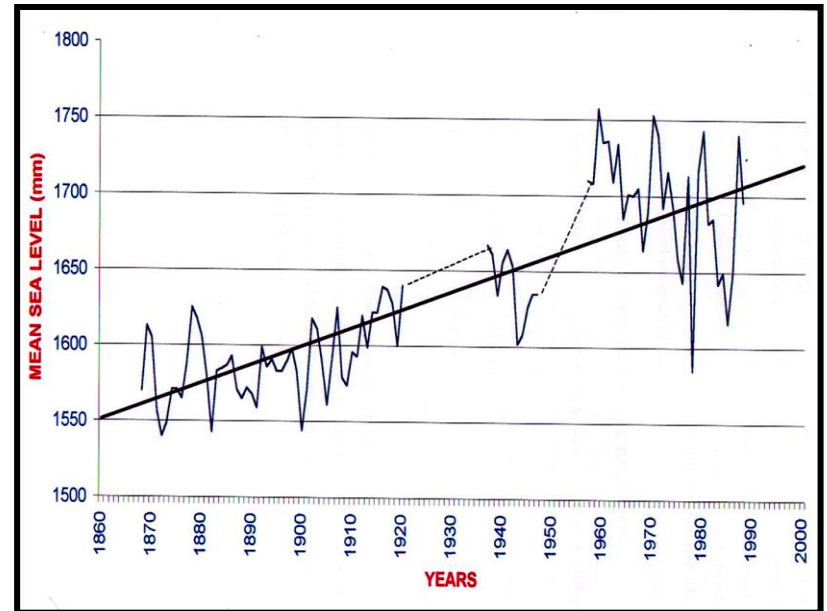


# Sea Level Rise (SLR)

## Sea Level Risks - Middle East



Trend of the Sea level Rise at Karachi.  
The present rate is 1.1mm/year.



Source: <http://www.psmsl.org>

## Extreme Weather Events (cyclones, floods,...)

- The period of 100 years 4 cyclones landed at Balochistan Coast and about 15 Cyclones landed on Sindh Coast.
- During the last 109 years about 51 severe cyclonic storms have been reported from the Arabian Sea. May - June and Oct - Nov are favorable periods for the formation of cyclonic storms in the Arabian Sea.

Kidwai et al., 2019

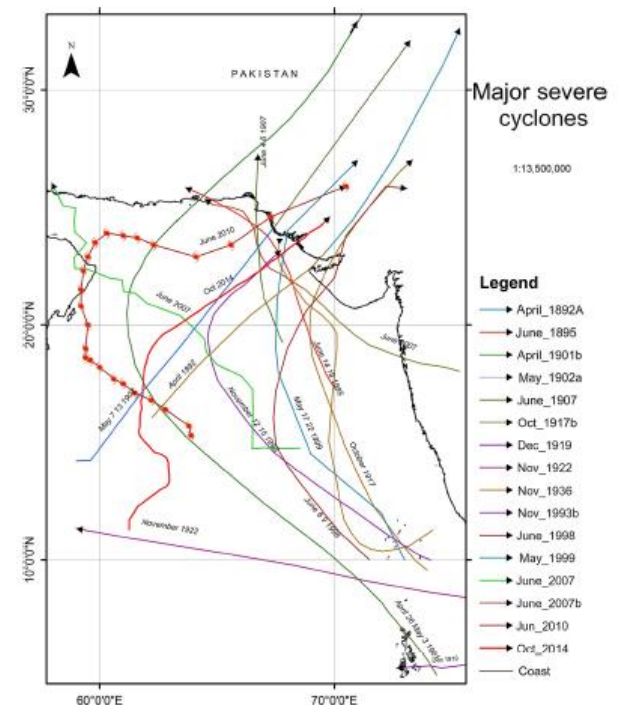
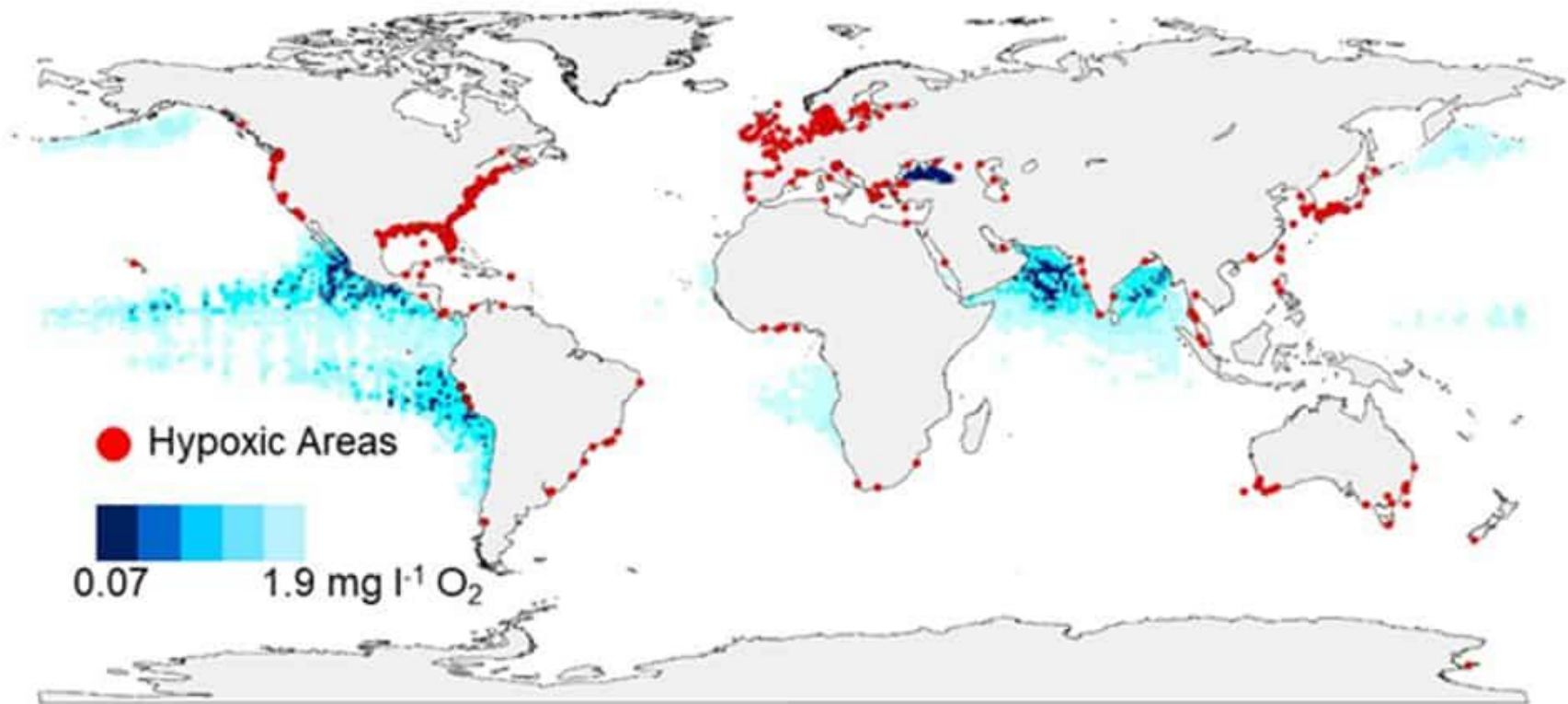


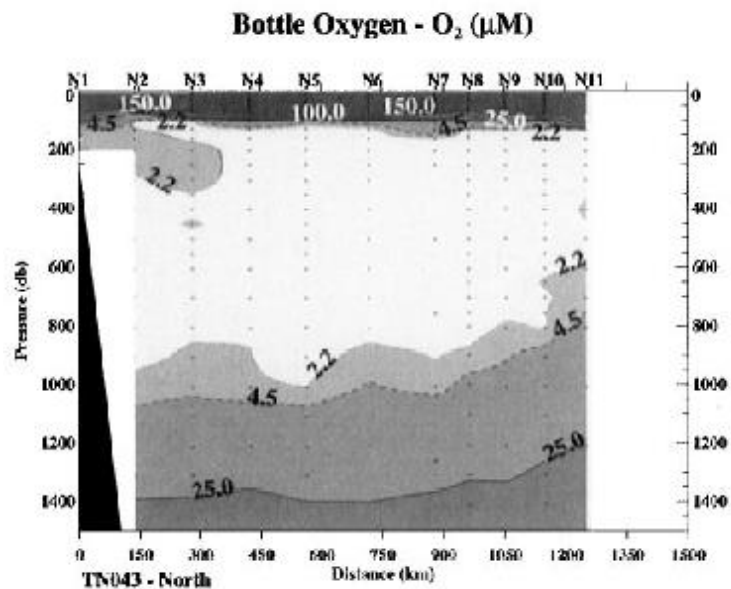
FIG. 6 Cyclone making landfall on the Pakistan coast. Legend shows the months and years of landfall.

## Oxygen Minimum Zone & Hypoxia

Oxygen-minimum zones in the open oceans have expanded by the size of the European Union (4.5 million sq km).



## Southwest M



## Northeast M

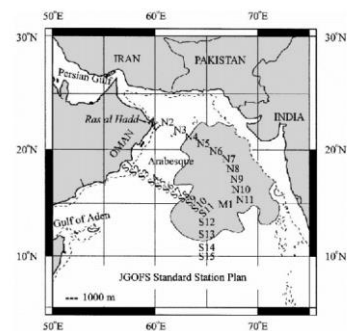
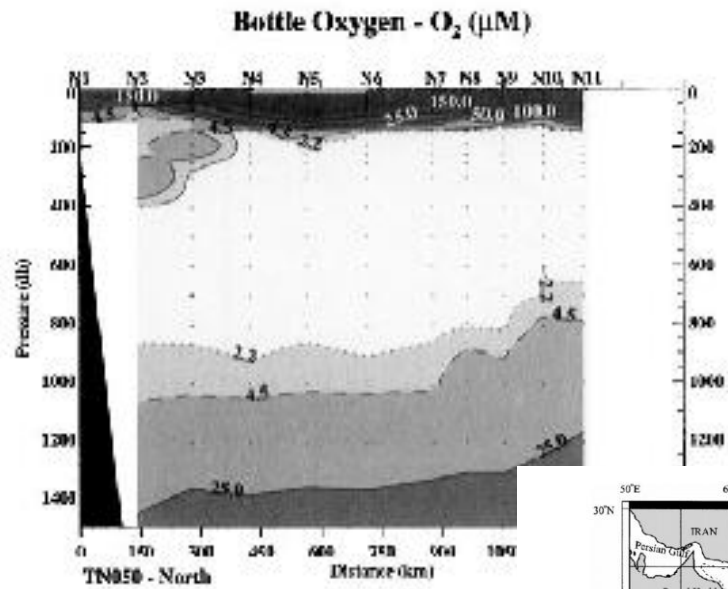
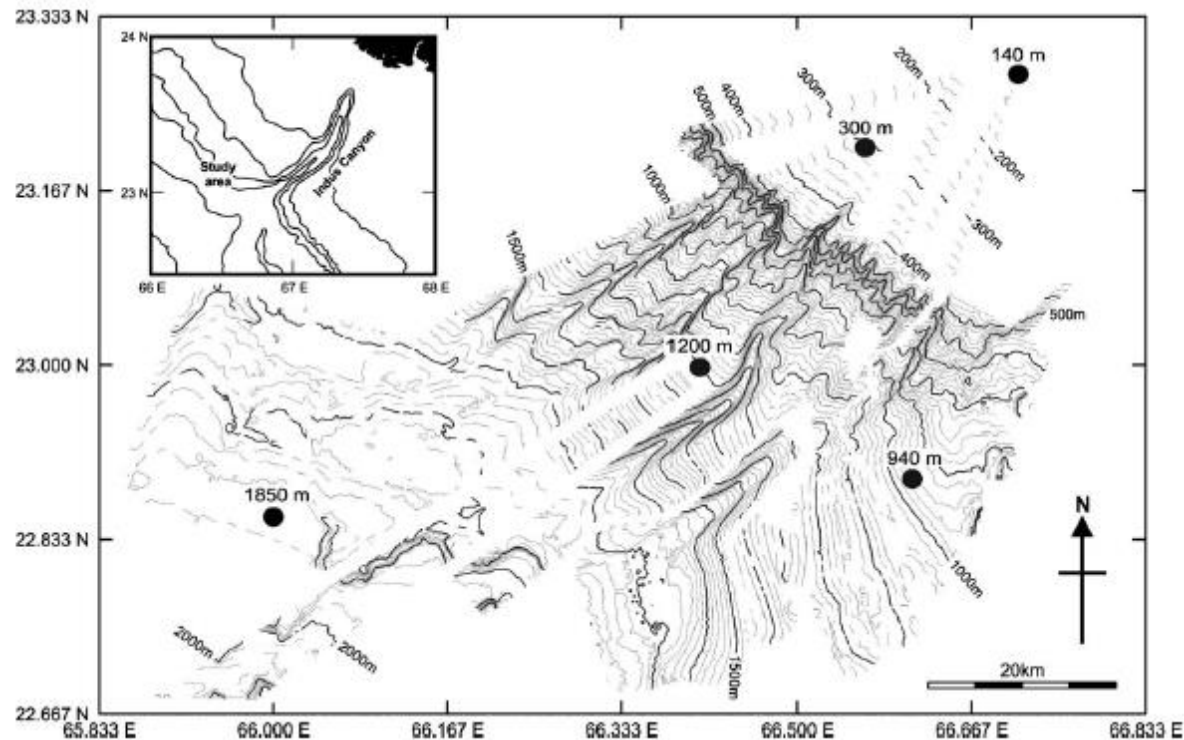


Fig. 1. Location and names of the standard station position for the US JGOFS Arabian Sea Process Study. The shaded region underlying the station grid gives a depiction of the horizontal extent of the quasi-permanent secondary nitric maximum regions described by Naqvi (1991).

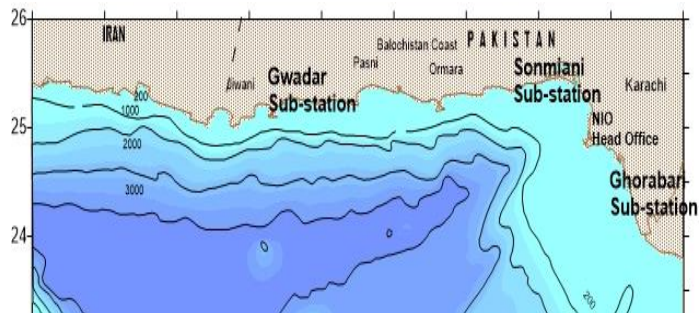


## Benthic biological and biogeochemical patterns and processes across an oxygen minimum zone (Pakistan margin, NE Arabian Sea)



# NANO - DOAP

A global study of coastal Deoxygenation, Ocean Acidification and Productivity at selected sites



NIO PARTICIPATES IN DECLARATION OF MARINE PROTECTED AREAS, UNDER THE UN CONVENTION ON CONVENTION ON BIOLOGICAL DIVERSITY (CBD)

Astola Island to be country's First Marine Protected Area (MPA)



PASNI, Apr 4 (APP): Astola Island will soon be declared the country's first "Marine" Protected area through absolute consensus among all concerned stakeholders, said Federal Minister of Climate Change, Zahid Hamid said here on Tuesday.



ECOLOGICAL SURVEY OF ASTOLA BEGINS

# Fishery Resource Appraisal Project (FRAPP)

- 2009- FV Ferdows
- 2010 Inshore- before the “super floods”
- After the super flood
- 5 months later- during the RV Dr. Fridtjof Nansen cruise (Nov )offshore Sindh coast-
- 2013-2014 Creek Survey Program
- 2015- February 2015 demersal stock (FV Ferdows)

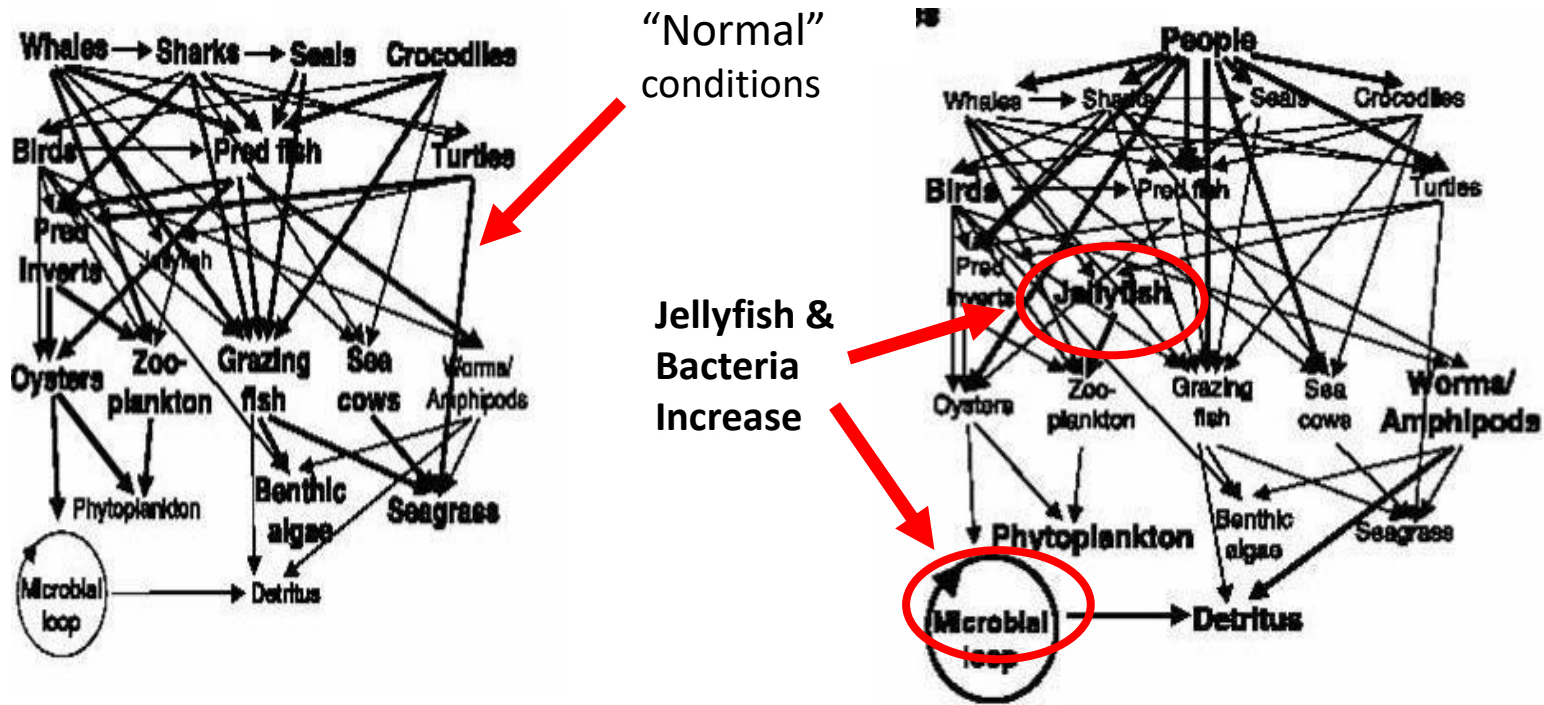


# 'Rise of Slime'

## Estuaries

Pre 1800's

Present



Jackson et al., 2001; slides borrowed from Dr. Rob Condon 2008

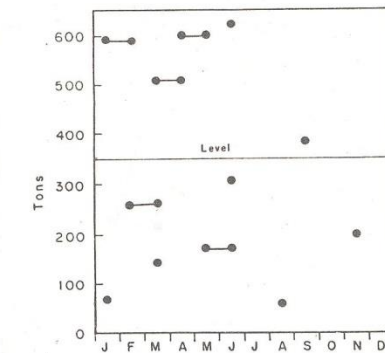
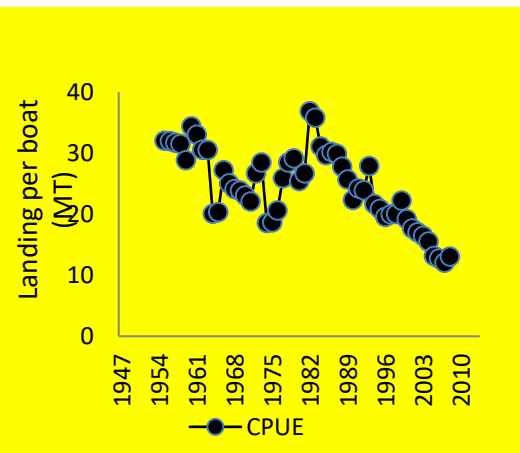


Fig 8a. Demersal Stocks Assessment by acoustic techniques R/V "F" Nansen 1975 - 1984. after: Abildgaard et al. Project Report) Survey area from meters depth to 150 miles offshore.



### Shifting baselines

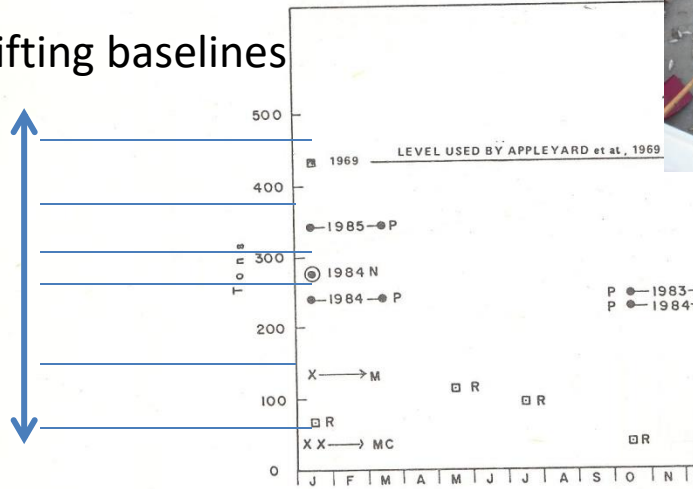


FIG. 8 b ESTIMATED DEMERSAL STOCKS :  
 P - PROJECT MARINE FISHERIES DEVELOPMENT 1983 - ( FROM 10 TO 200 m DEPTH )  
 N - DATA FROM " F. NANSEN " ( RANDOM SAMPLING F 15 TO 150 MILES OFFSHORE )  
 R - RUSSIAN EXPEDITION 1969 ( OUT SIDE 12 MILES: 21 230 METER DEPTH )  
 M - FORMER " MACHHERA " 1960 - 1967 ( FROM 5 TO 7 DEPTH ).  
 MC - " MACHHANDRA " 1966 - 1969, COMMERCIAL FISH ( FROM 5 TO 75 m DEPTH )

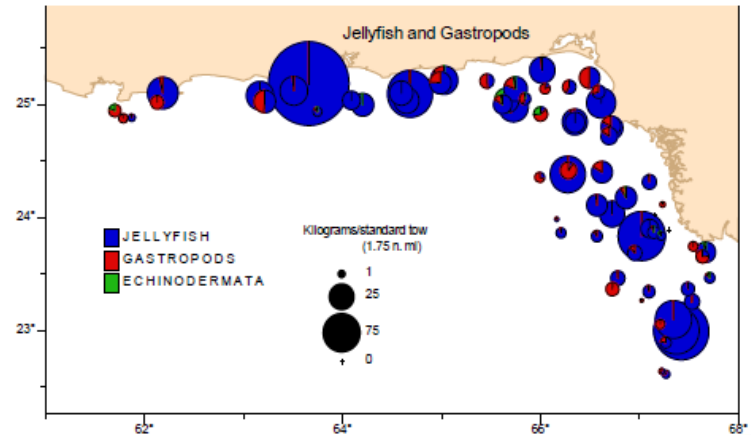
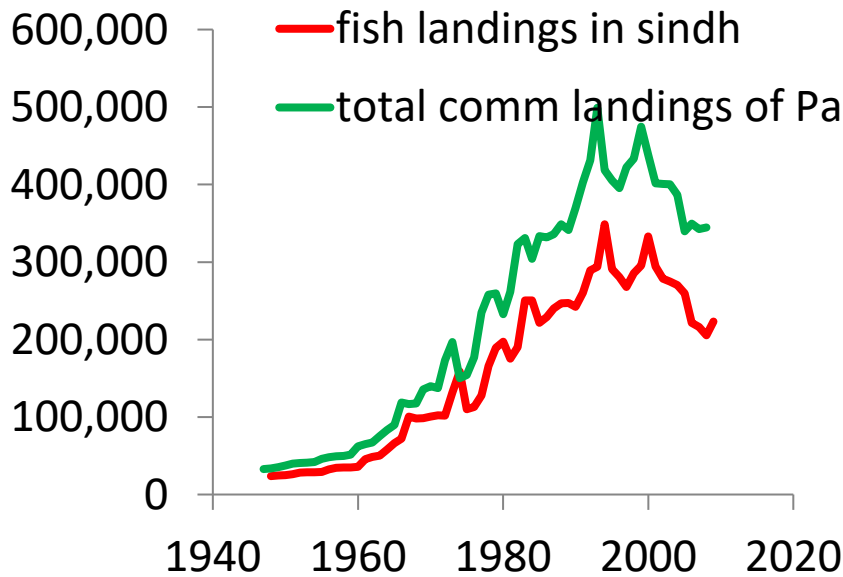


Figure 6m: Catch distribution and stratified analysis of jellyfish (Jellyfish) gastropods and Echinodermata from Pakistan demersal survey 2010/409

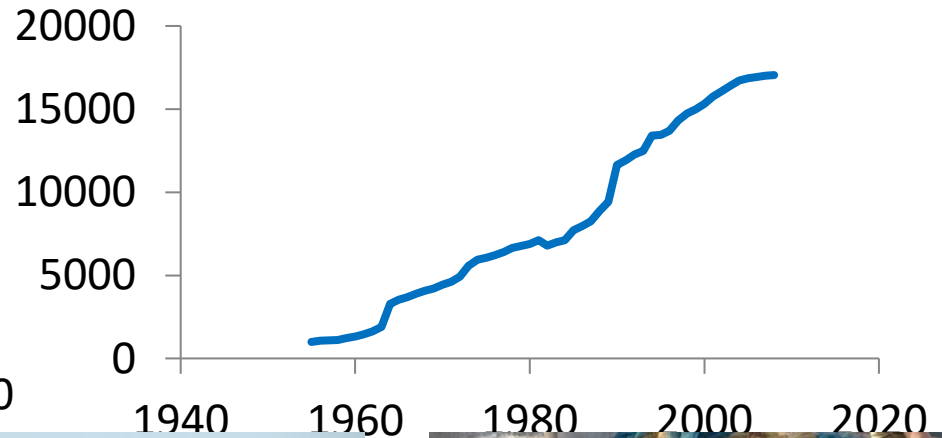


# Traditional information > 60% fishery on the shelf is supported by the Indus delta



## Livelihood dependence on fishing

### total vessels in Sindh

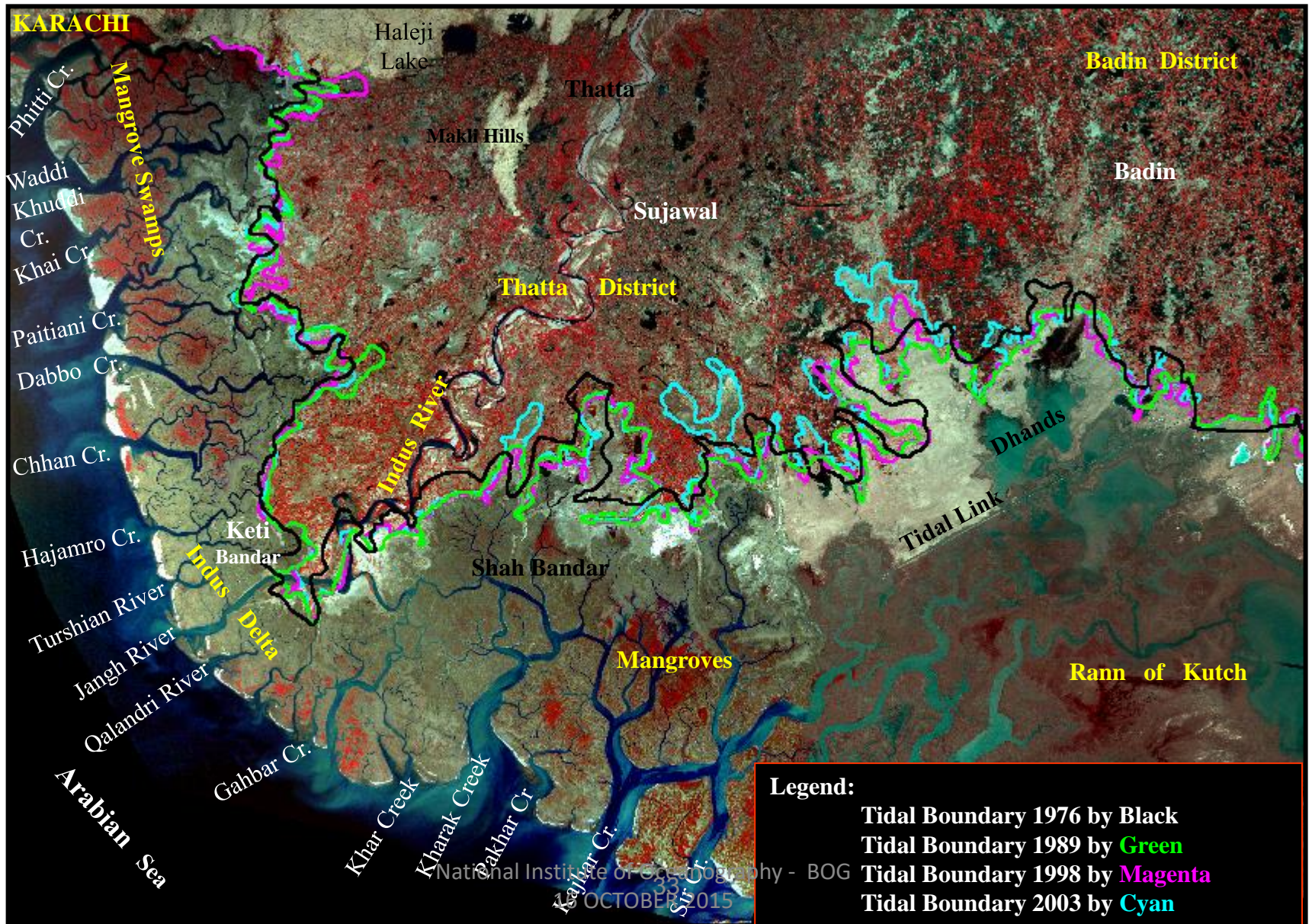


Data source: Marine Fisheries Department, GOP





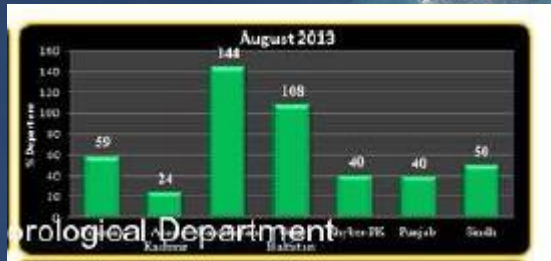
# Seawater Intrusion





## August 2013

August brought wetter conditions over most parts of the country with very-much-above-average rainfall in the Balochistan and Gilgit-Batatan area, and large areas of record high falls in Lahore, Sialko and Gujranwala. For the month of August 2013, rainfall for the country as whole was exceptionally on higher than normal (59 %) side and was ranked 9<sup>th</sup> heaviest monthly rainfall since 1961 The monthly rainfall over Balochistan (144%), Gilgit-Baltistan(108%) and Sindh (50%) was largely above normal, whereas provinces of Khyber-Pakhunkhwa (40%), Punjab (40%) and Azad Kashmir (24%) had witnessed moderately above normal rainfall.



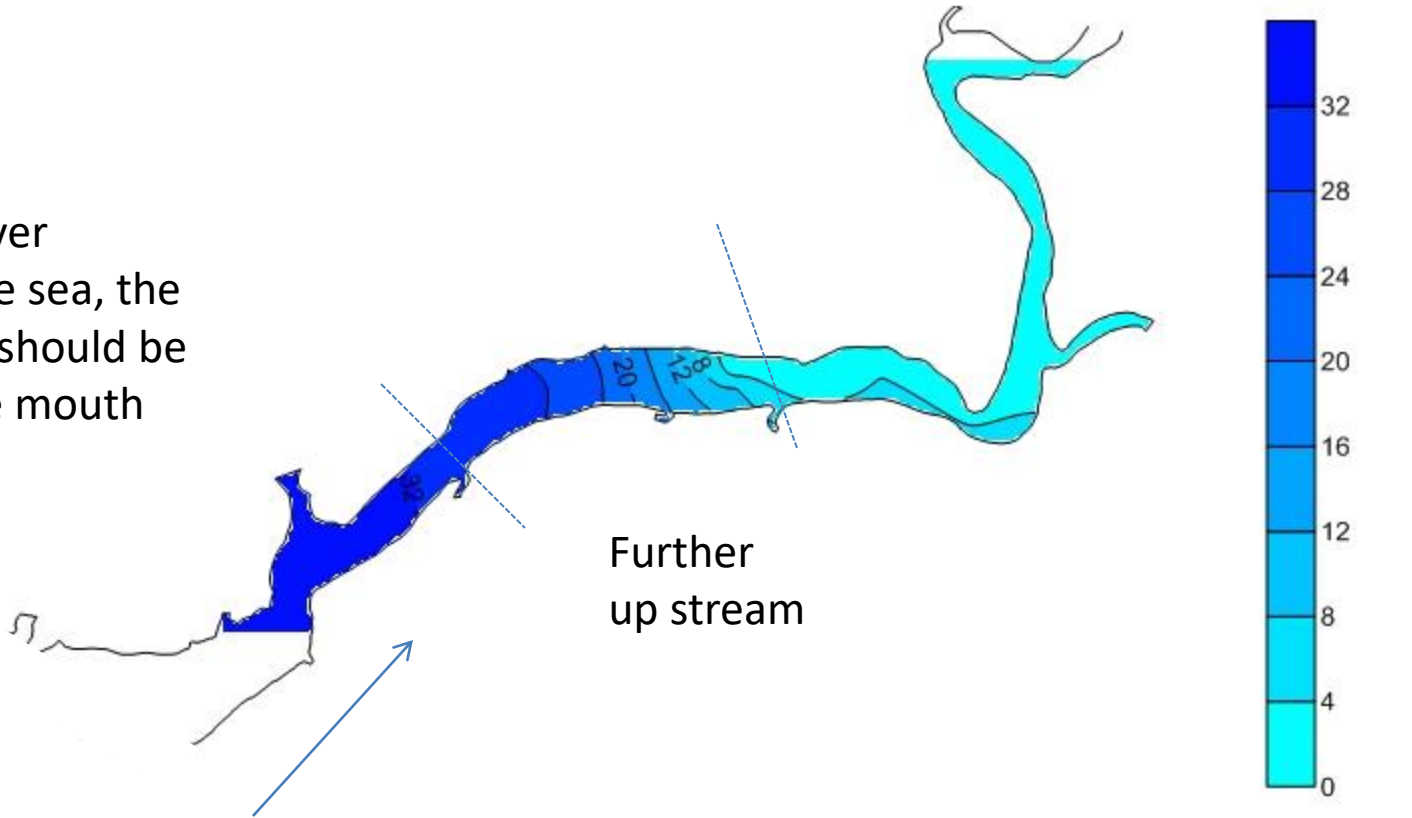
August 2013  
Salinity 0.21

1. Direct connection to sea
2. Direct connection to river
3. Un connected smaller creeks

Observations at ebb tide

# Estuary moves upstream?

With the river entering the sea, the salt wedge should be close to the mouth



Further up stream

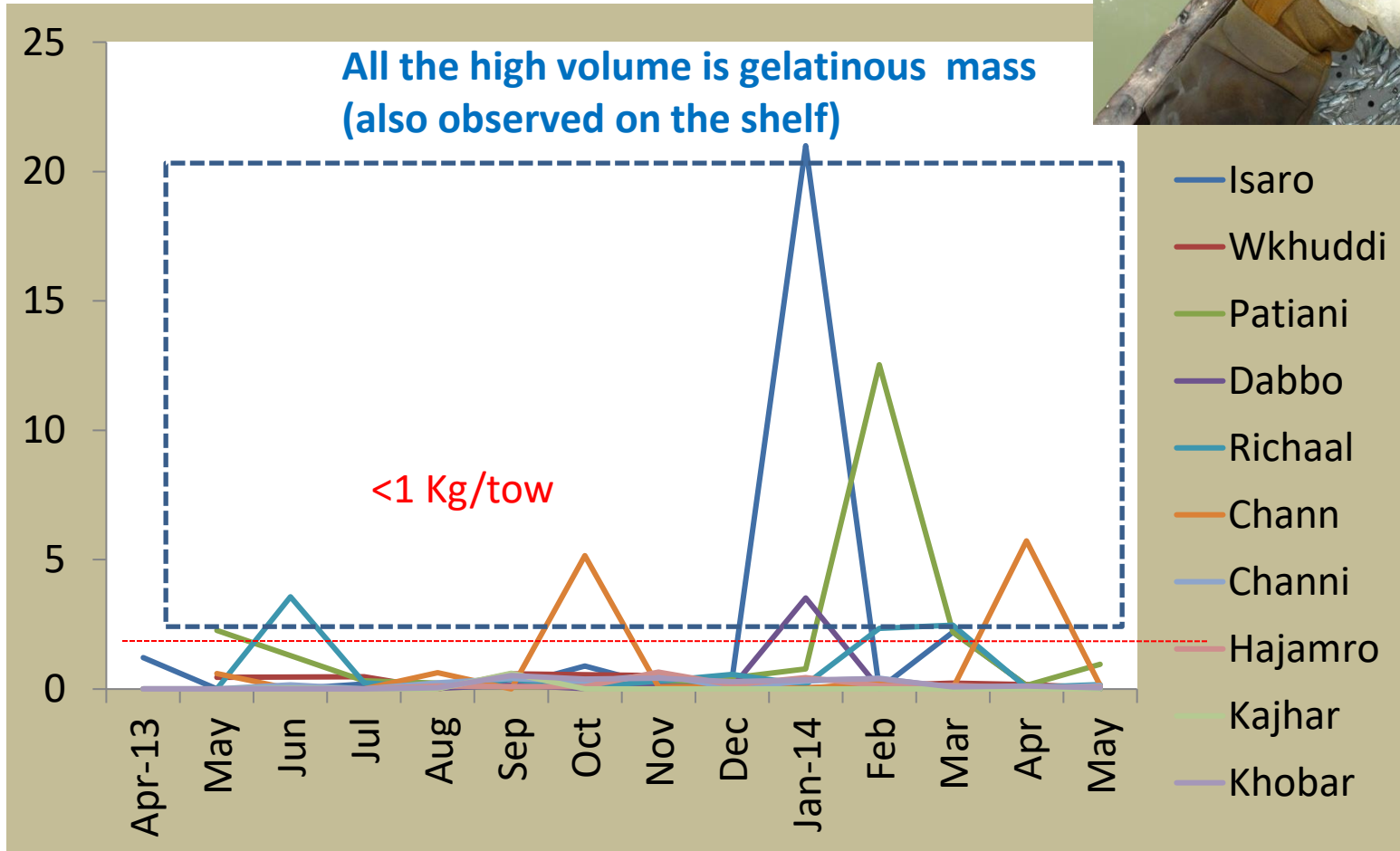
River Indus delta

**What's happening to the estuarine ecosystem of the delta?**

C Shelf 36 PSS



# Fish (mixed) catch per tow over the study period April 2013 – May 2014 in the creeks of the Indus delta







2021 United Nations Decade  
2030 of Ocean Science  
for Sustainable Development

# MegaDelta Programme



Mega-Delta Program: Partner deltas



**MEGA-DELTA**

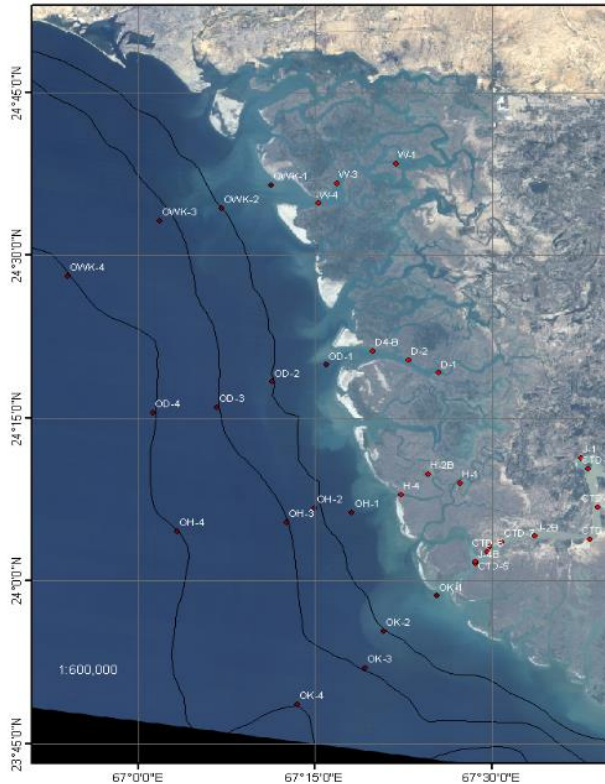
Deltas associated with large rivers: Seeking solutions to the problem of sustainability



華東師範大學  
East China Normal University



# Research Interest





## Mega-Delta Decade Programme



### Lead Institution

State Key Laboratory of Estuarine and Coastal Research  
East China Normal University

Contact: Xiuzhen Li  
megadelta@ecnu.edu.cn

---

#### KEY PARTNERS

- Faculty of Civil Engineering and Geoscience, Delft University of Technology, Netherlands
- Faculty of Science, Kafrelsheikh University, Egypt
- College of the Coast & Environment, College of Science, and School of Renewable Natural Resources, Louisiana State University, USA
- National Institute of Oceanography (NIO), Pakistan
- National Institute for Research and Development of Marine Geology and Geoecology (GeoEcoMar), Romania

---

#### DECADE CHALLENGES ADDRESSED

**CHALLENGE 2:** Protect and restore ecosystems and biodiversity

**CHALLENGE 6:** Increase community resilience to ocean hazards

**CHALLENGE 9:** Skills, knowledge and technology for all

---

#### OCEAN BASINS

North Atlantic    Indian  
South Atlantic    Arctic  
North Pacific

ECNUER
Indian
ECNUER

Coasts



### Summary

River deltas are a critical coastal habitat, however, they are facing continuous threats such as increased erosion, flooding risk, and shrinking salt marshes and mangroves. This has become a global problem which requires international cooperation to find solutions. The **Mega-Delta Programme** will study the present status and threats facing 25 globally representative deltas, create methodologies for new blueprints including critical characteristics and the sustainability of the delta system and its capacity to support regional development for deltas having different physical processes and ecological and economic value. The overall objective of the programme is to support sustainable development in delta regions.

Duration: 01/01/2021 - 12/31/2030

---

### Priority Activities (first 2 years)

- Stimulate interactions with experts and collect information from 15 representative deltas to establish a baseline inventory on the status and threats
- Share knowledge on the results through special publications
- Organize an International Conference on Estuaries and Coasts (ICEC-2021)
- Organize an International Conference on Physics of Estuaries and Coastal Seas (PECS2022)
- Create an eventual road map for sustainable delta development which considers climate change, geoscience, engineering, ecology, and society at the global and centennial scales

"We are excited to be part of UN Ocean Decade, an invaluable international collaborative effort we should keep on cultivating."  
*Prof. Nina Lam, E.L. Abraham Distinguished Professor of Louisiana Environmental Studies, Louisiana State University, USA*

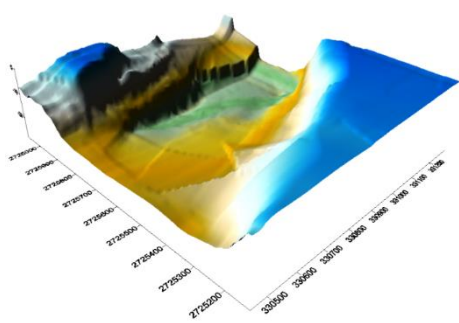
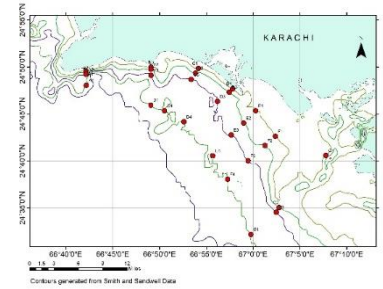
"Through the Ocean Decade, I look forward to helping address the many threats facing our deltas and encouraging sustainable actions and solutions across the globe."  
*Alaa Salem, Professor of Kafrelsheikh University, Egypt*



MEGA-DELTA

Deltas associated with large rivers: Seeking solutions to the problem of sustainability

Implementation of International Collaborations, Pak-China Collaboration, NIO-ECNU (SKLEC) Executive Agreement of Scientific Collaboration





# Coastal Erosion , Inundation and flooding along Pakistan coast



# SLR along the Pakistan coast

Coastal Erosion & Accretion

Displacement Of Wetlands And Lowlands

Estuaries And Freshwater Aquifers

Increased Vulnerability To Coastal Storm Damage And Flooding

Shoreline Changes

Altered Tidal Ranges In Rivers And Bays

Changes in Sedimentation Patterns

Coastal Inundations

Change in Ecology

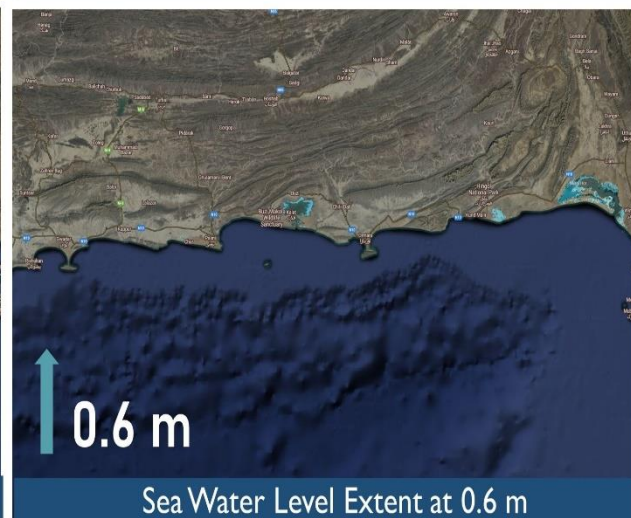
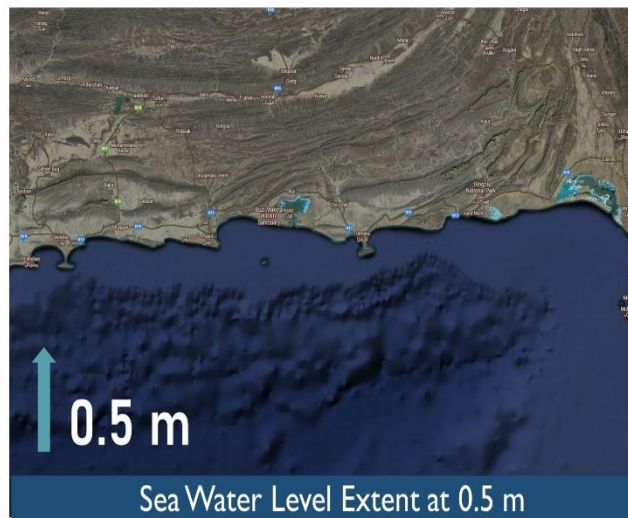
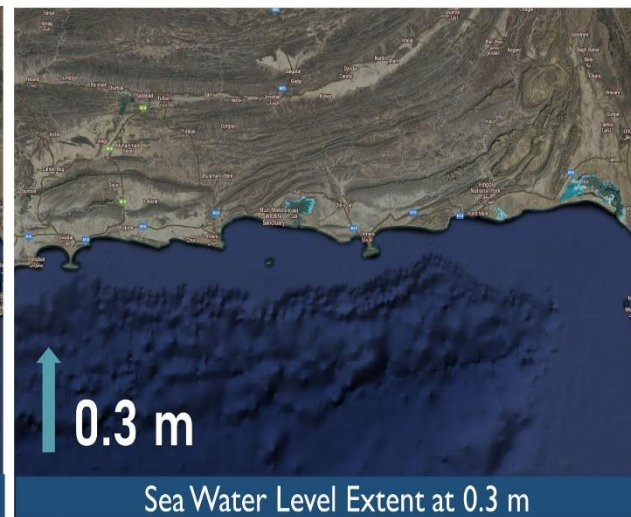
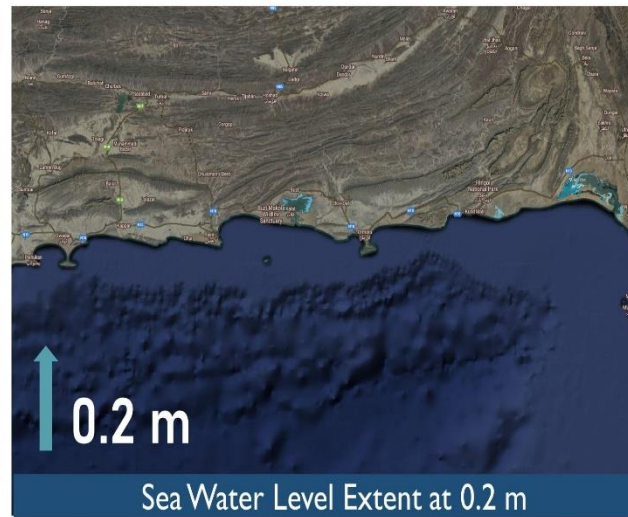
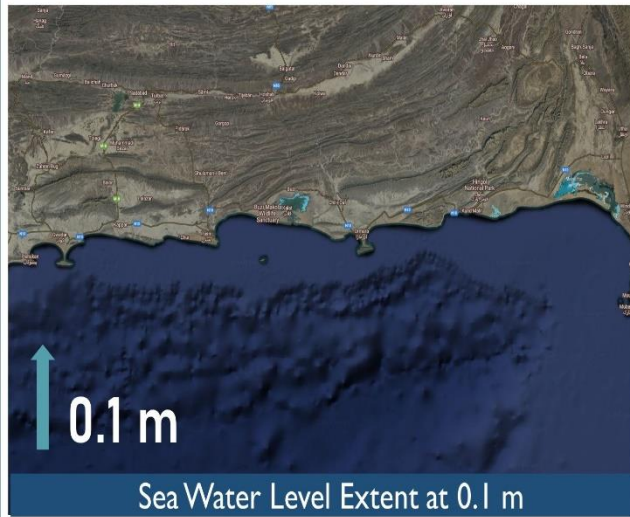
Increase In the Heights Of Waves







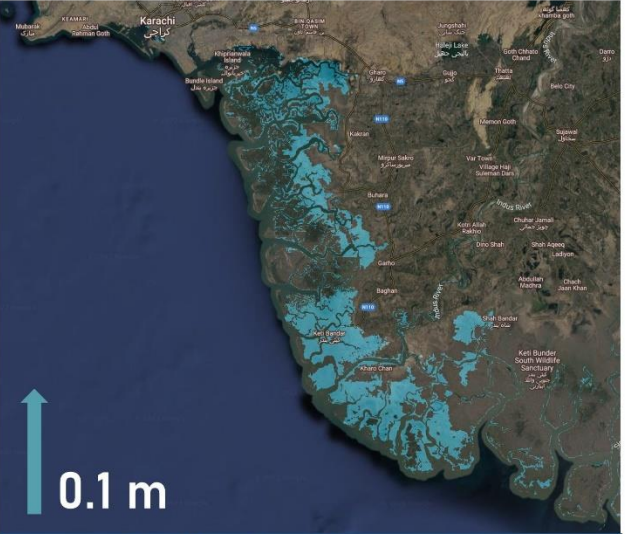
# Extent of Sea Level Inundation along Balochistan Coast as per IPCC Projections







# Extent of Sea Level Inundation along Sindh Coast as per IPCC Projections



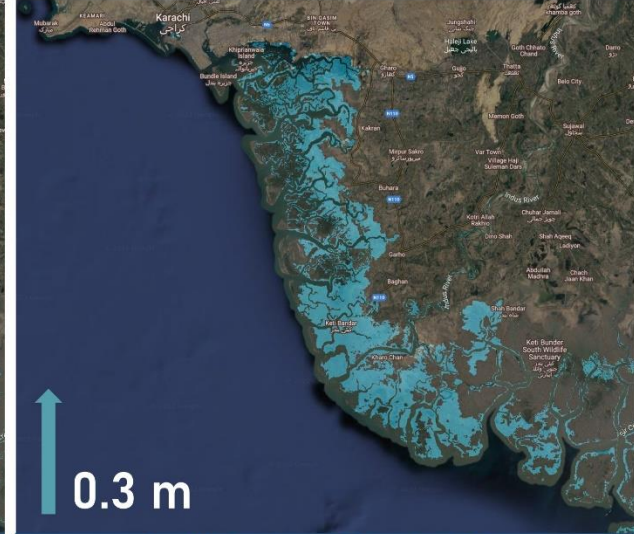
↑  
**0.1 m**

Sea Water Level Extent at 0.1 m



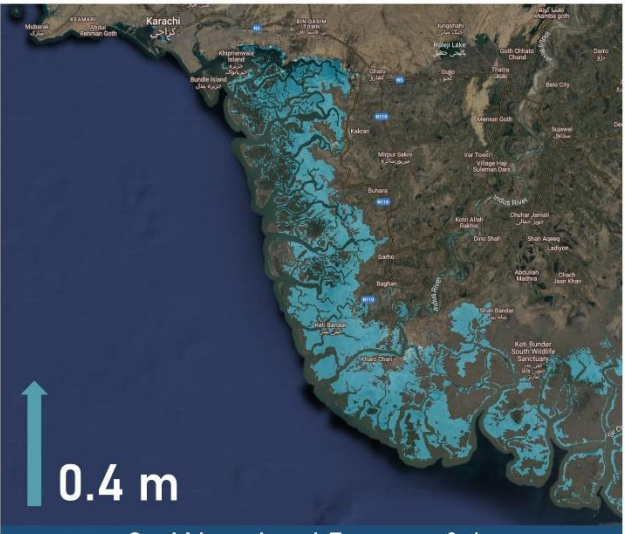
↑  
**0.2 m**

Sea Water Level Extent at 0.2 m



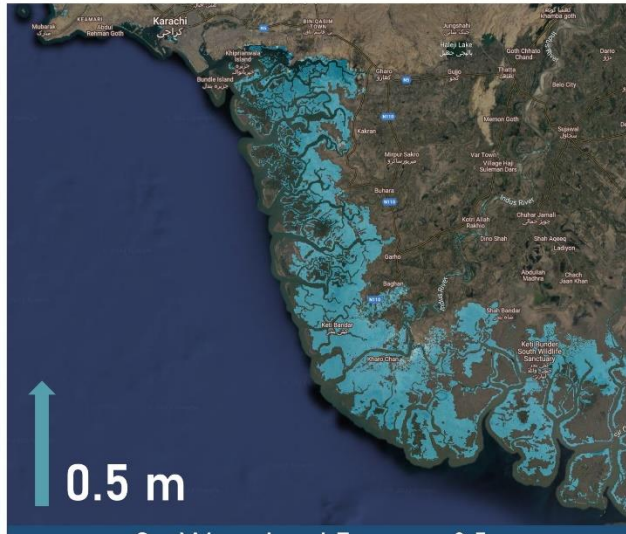
↑  
**0.3 m**

Sea Water Level Extent at 0.3 m



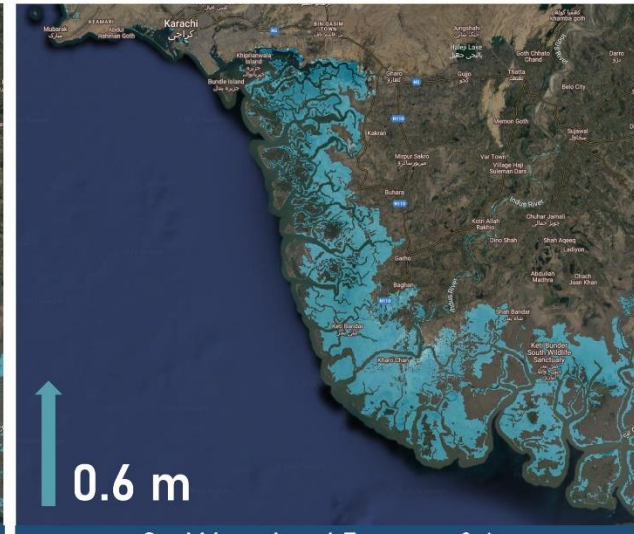
↑  
**0.4 m**

Sea Water Level Extent at 0.4 m



↑  
**0.5 m**

Sea Water Level Extent at 0.5 m

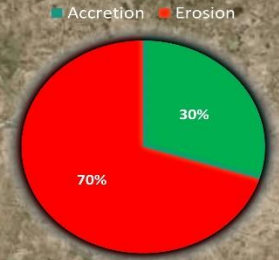


↑  
**0.6 m**

Sea Water Level Extent at 0.6 m



# EROSION & ACCRETION IN INDUS DELTA REGION FROM 2016-2022



 Erosion  
 Accretion

Karachi

Thatta

Sujawal

*Right Bank*

*Left Bank*

Korangi Cr.

Phitti Cr.

Khuddi Cr.

Khai Cr.

Patiani Cr.

Dabbo Cr.

Chan Cr.

Hajambro Cr.

Turshian Cr.

Khobar Cr.

Kahr Cr.

Wari Cr.

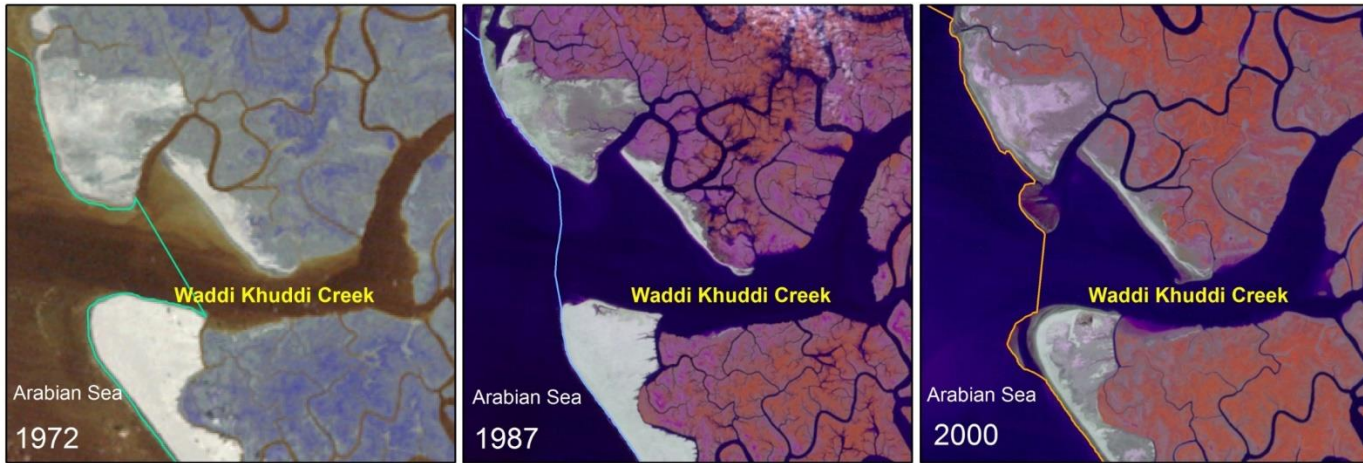
Kajhar Cr.

Sir Cr.

River





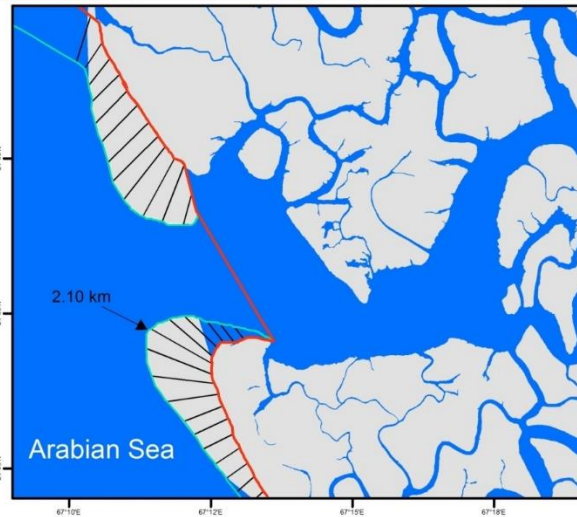
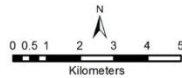


Change in coastline can be seen from 1972 to 2014 through 1987 and 2000.

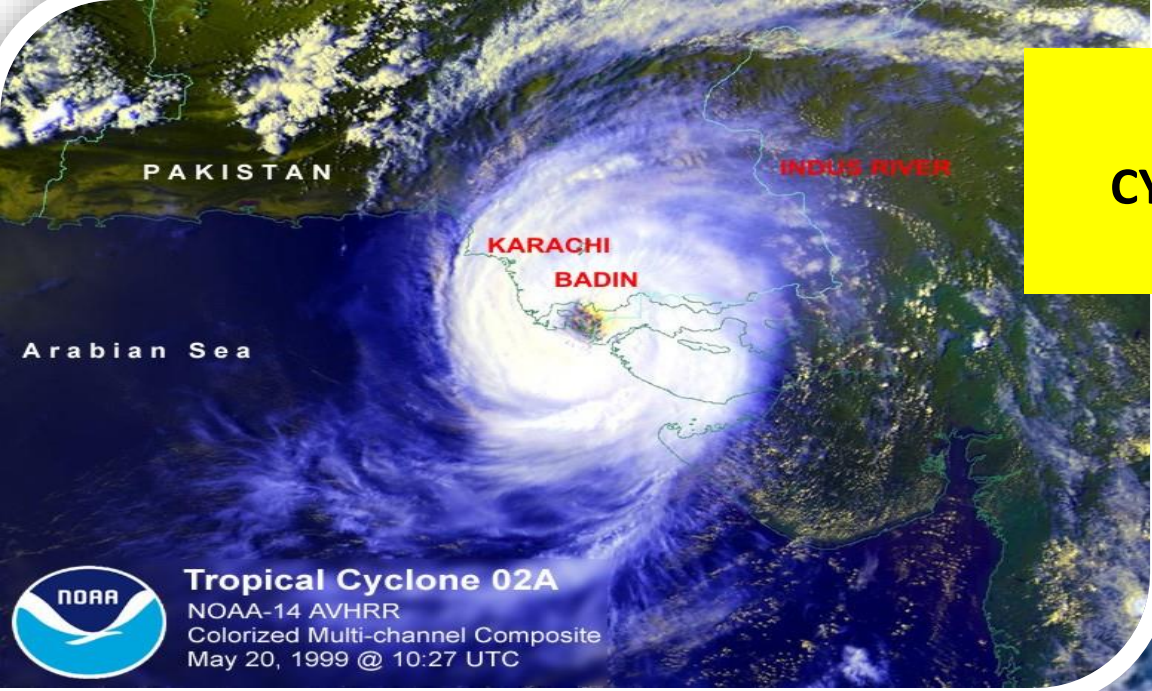
Arrow showing maximum land erosion about 2.1 km near Waddi Khuddi Creek .

**Legend**

- 1972 Coastline
- 1987 Coastline
- 2000 Coastline
- 2014 Coastline







# EXTREME WEATHER EVENTS

## CYCLONE 2 A – 1999 and Coastal Dhands System





**Tidal link drain Before  
Cyclone 2A 1999**

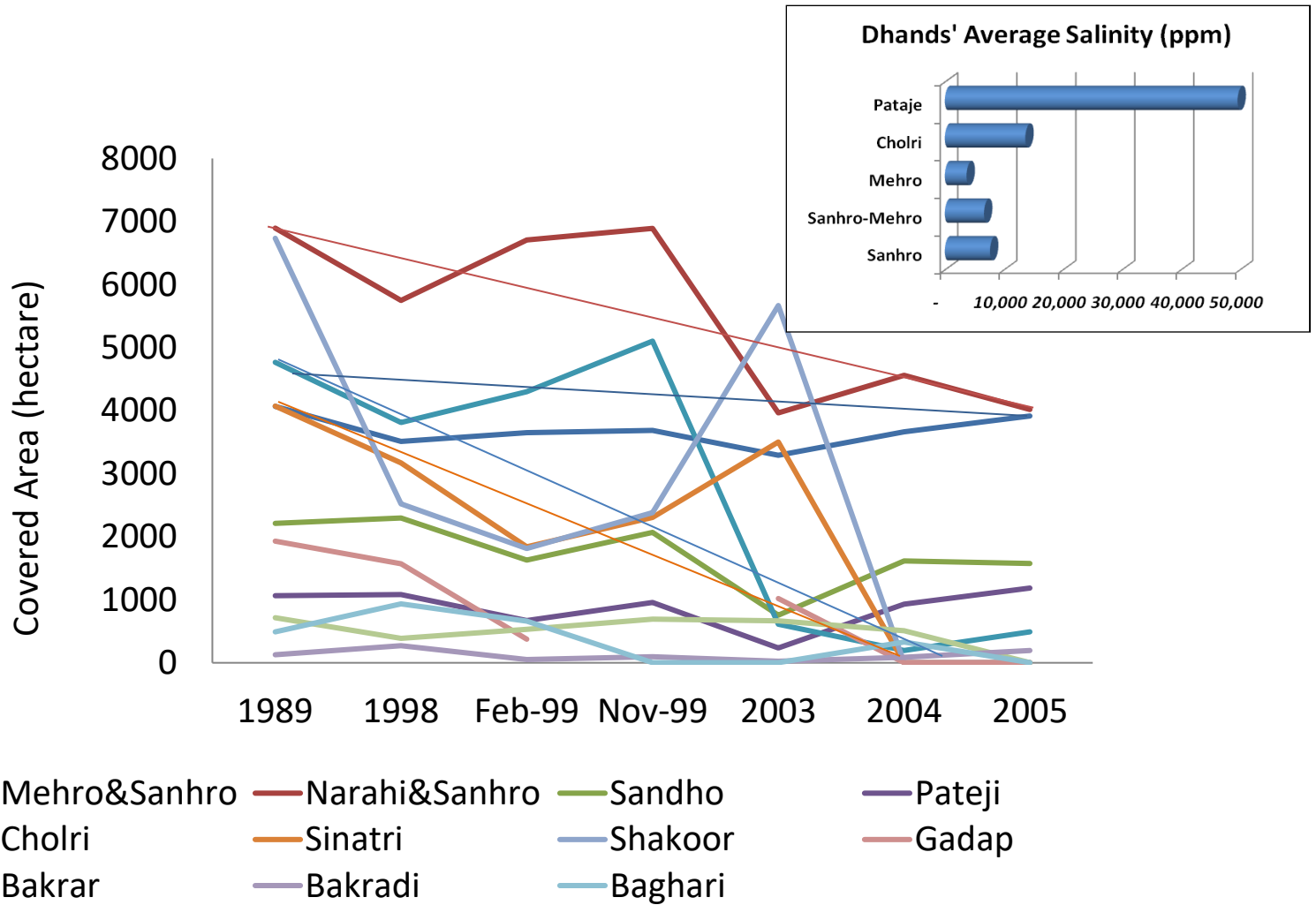
**After Cyclone**



6th South and Central Asia MAB Network  
(SACAM), meeting, Islamabad-Pakistan



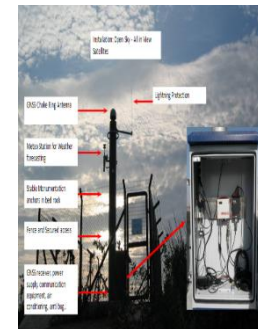
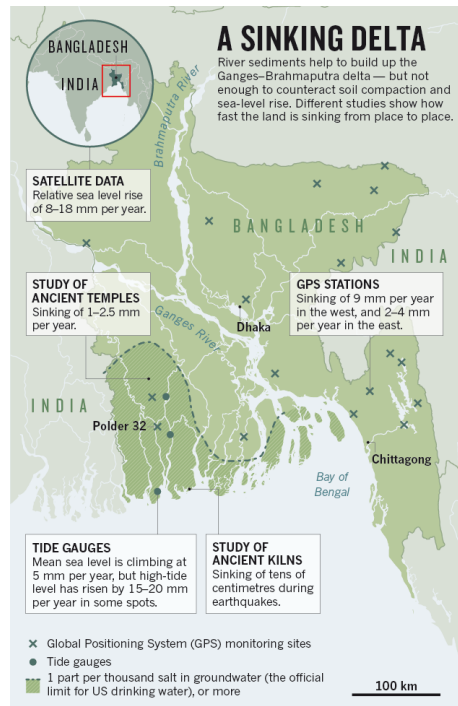
# Dhands- Indus Delta Region near Tidal Link



Figures from (NIO and SUPARCO Report, 2007)



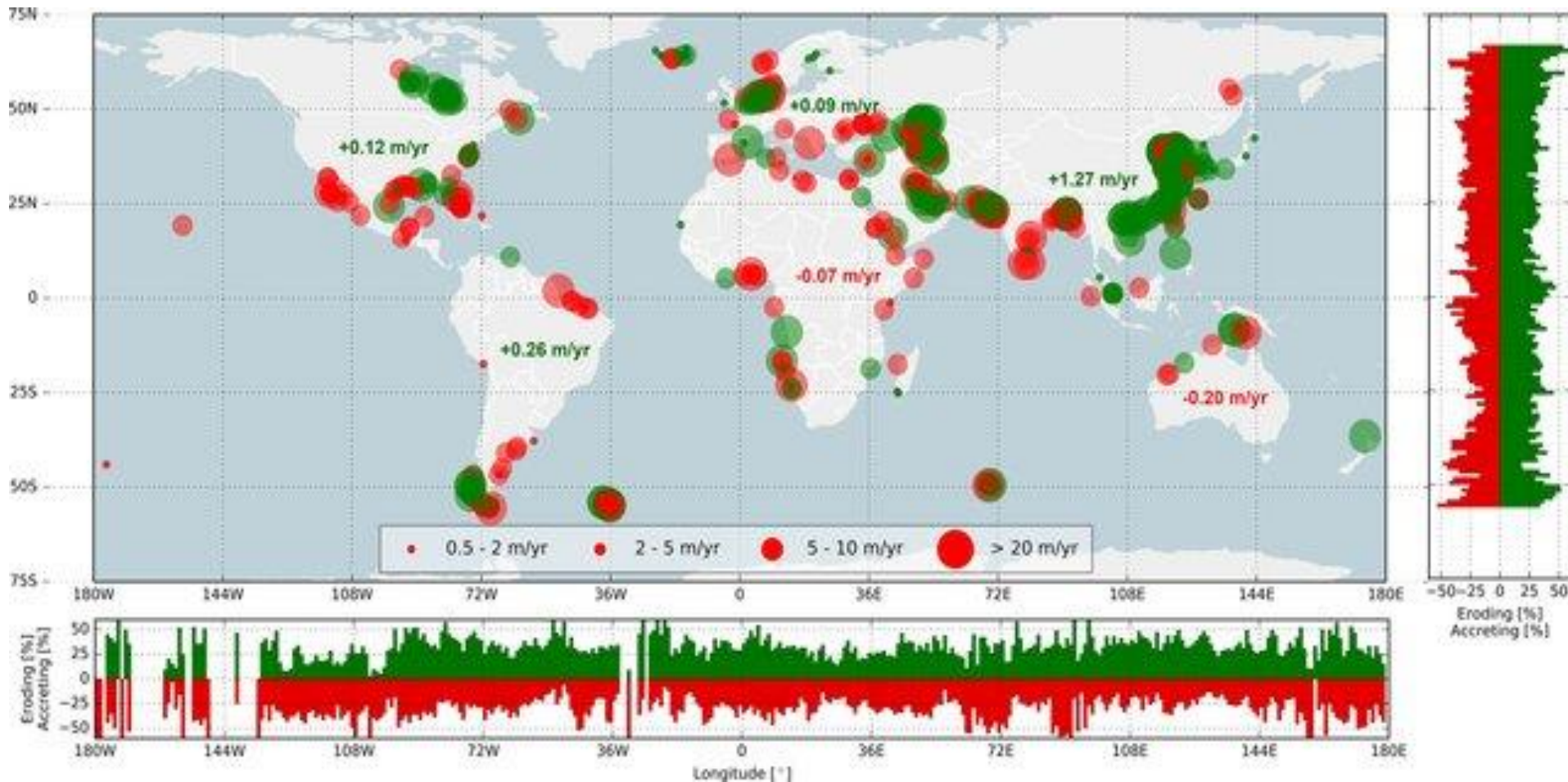
# MONITORING THE SEA WATER INTRUSION, SEA LEVEL RISE, COASTAL EROSION & LANDSUBSIDENCE ALONG SINDH AND BALOCHISTAN COAST”



## SEAWATER INTRUSION AND LAND SUBSIDENCE



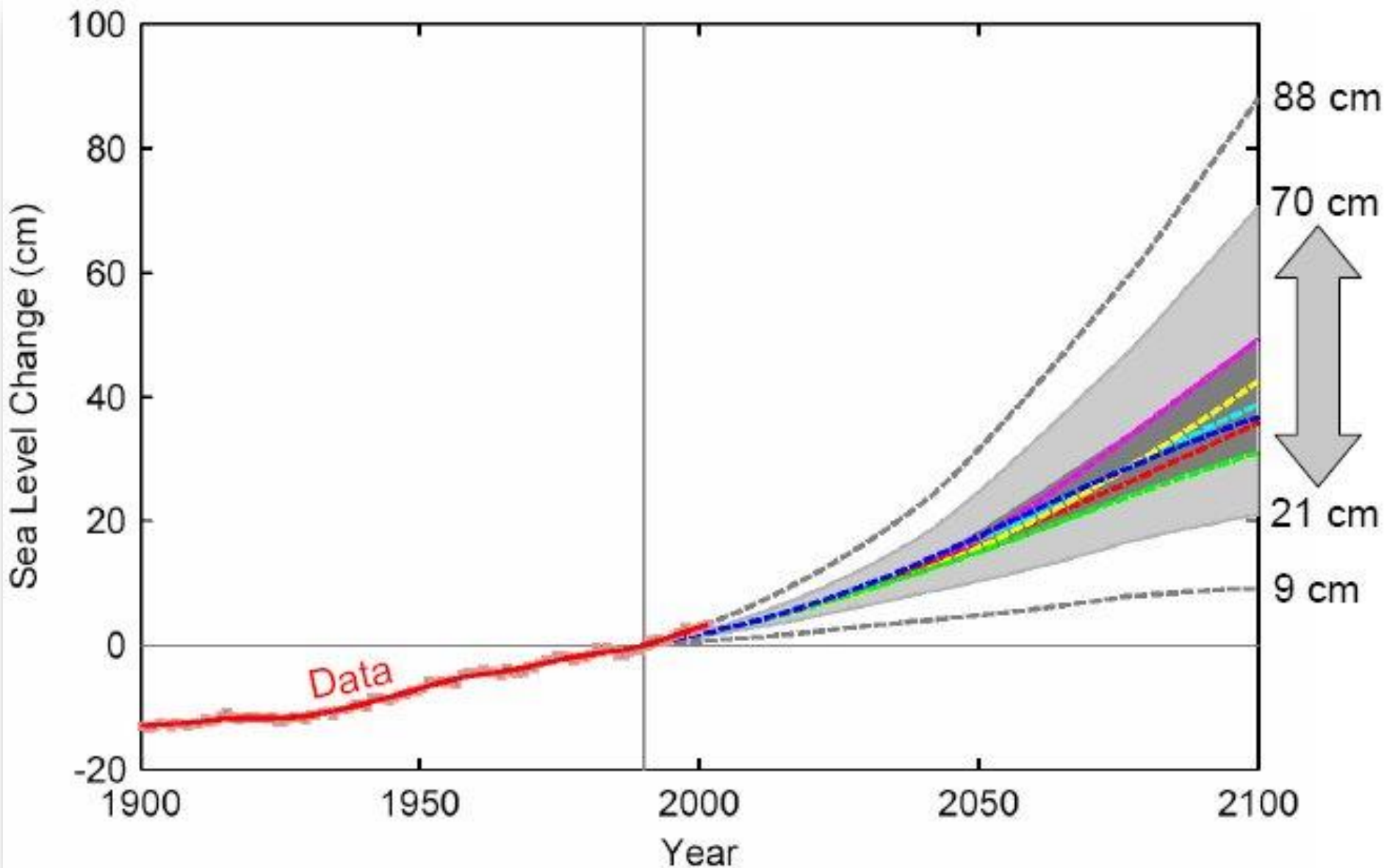
Global hotspots of beach erosion and accretion; the red (green) circles indicate erosion (accretion) for the four relevant shoreline dynamic classifications



*Nature scientific reports (2018) 8:6641 doi:10.1038/s41598-018-24630-6*



# Sea Level Change



# Vulnerable Areas/Regions

## Rising waters

Sea levels going up 60 percent faster than previous UN climate panel forecasts, scientists report Wednesday

### Largest cities exposed to risk by 2070

Most vulnerable to surge-induced events, by projected population

Millions

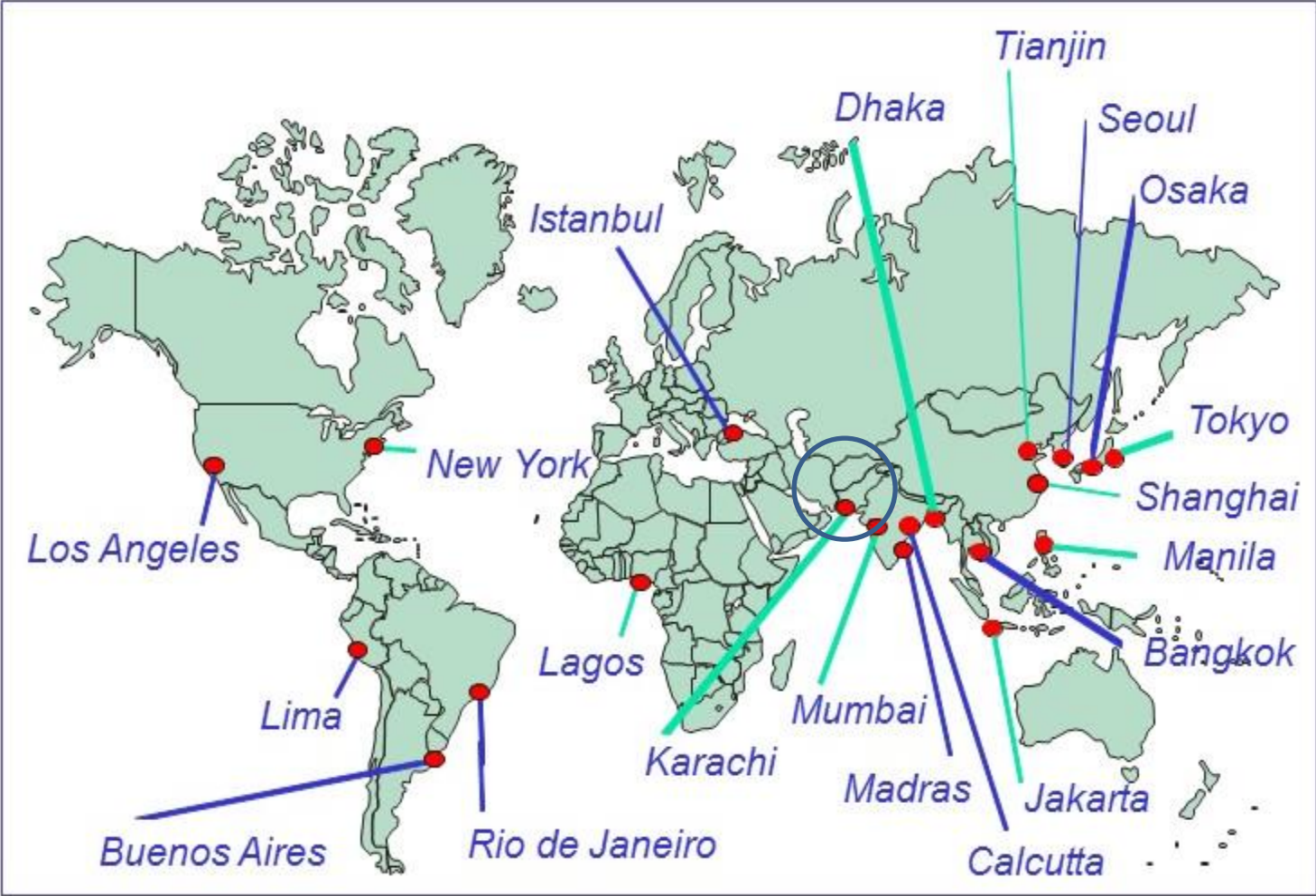


Source: OECD

AFP

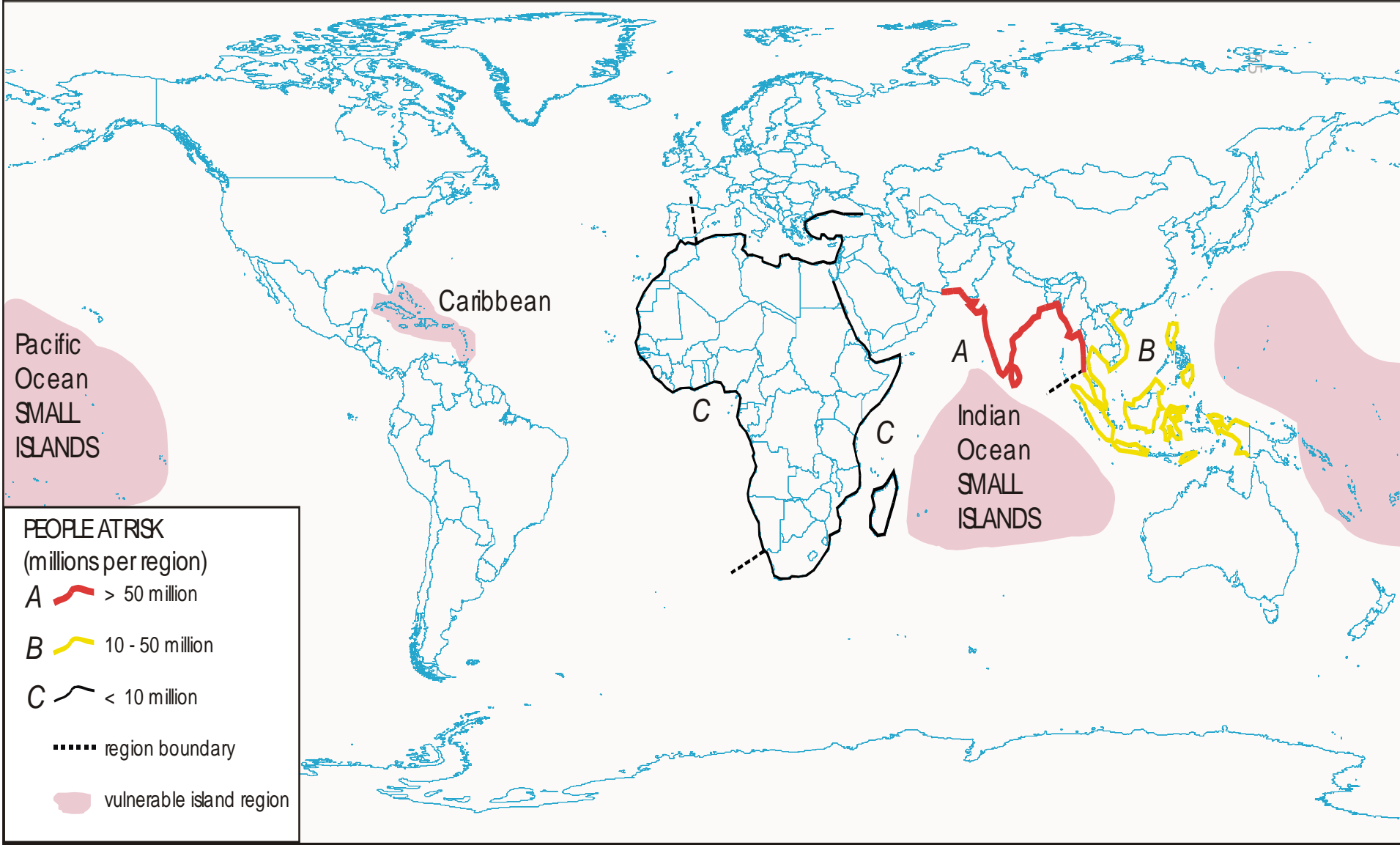
- Deltas
- Ice-dominated coasts
- Small islands
- Low lying cities

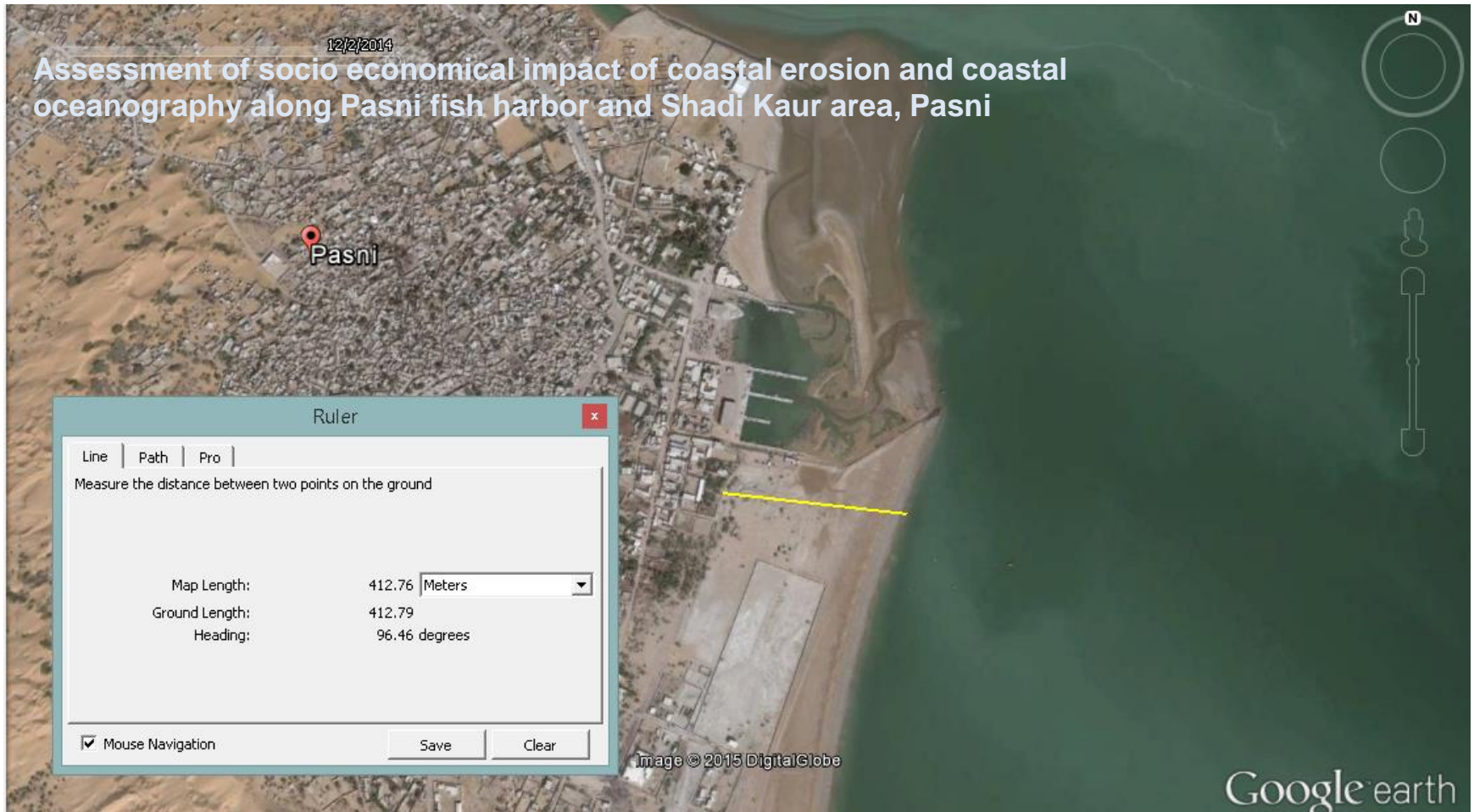
# MAJOR CITIES OF THE WORLD EXPOSED TO THE THREAT OF SEAWATER INTRUSION





The worst case predicted is for southern Asia, where more than 50 million people could be at risk from flooding each year by the 2080s (Nicholls et al., 1999).





413m progression of coastline from 1990 till 2014 (~17m/year)

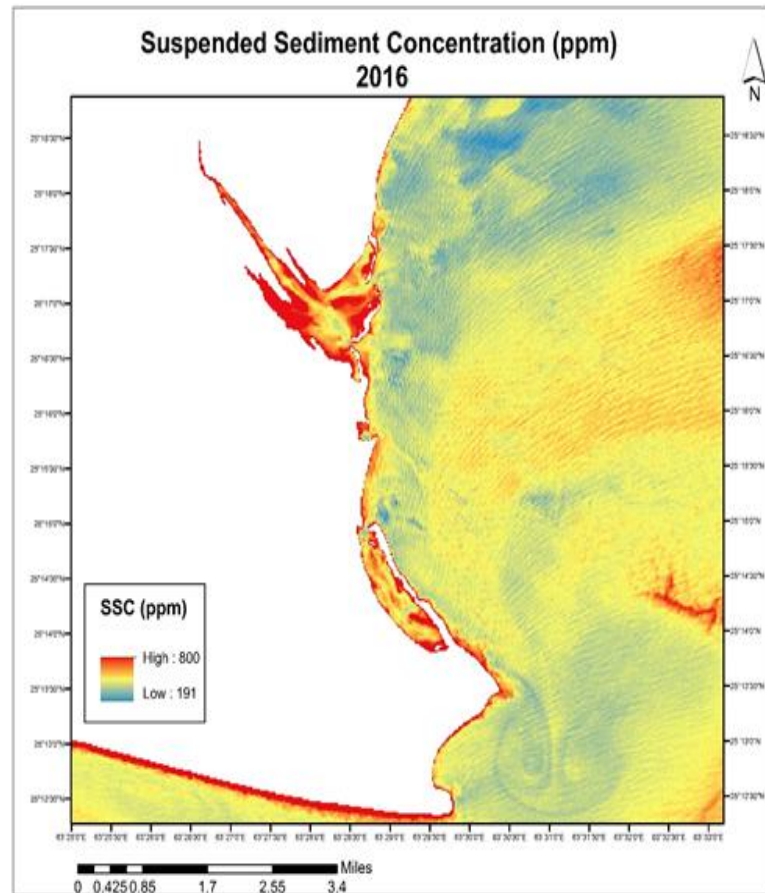
## SURVEYS TO STUDY SEVERE EROSION AT SHADI KAUR

NIO is undertaking a detailed study to identify factors responsible and to propose mitigation plan to protect Pasni





- Shoreline Analysis
- Suspended Solid Temporal analysis using Modeling and In situ results.
- Identification of Erosion Hotspots



Estimated Suspended Sediment concentration in particles per million in May 2016. High value of estimated SSC is 800 and minimum estimated value of SSC is low is 191.

# Sonmiani DAMB Survey

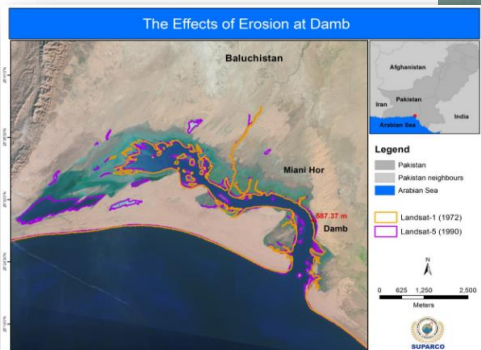


Image 2013

Around 175 m since 2004

April 2017



00:00

2004

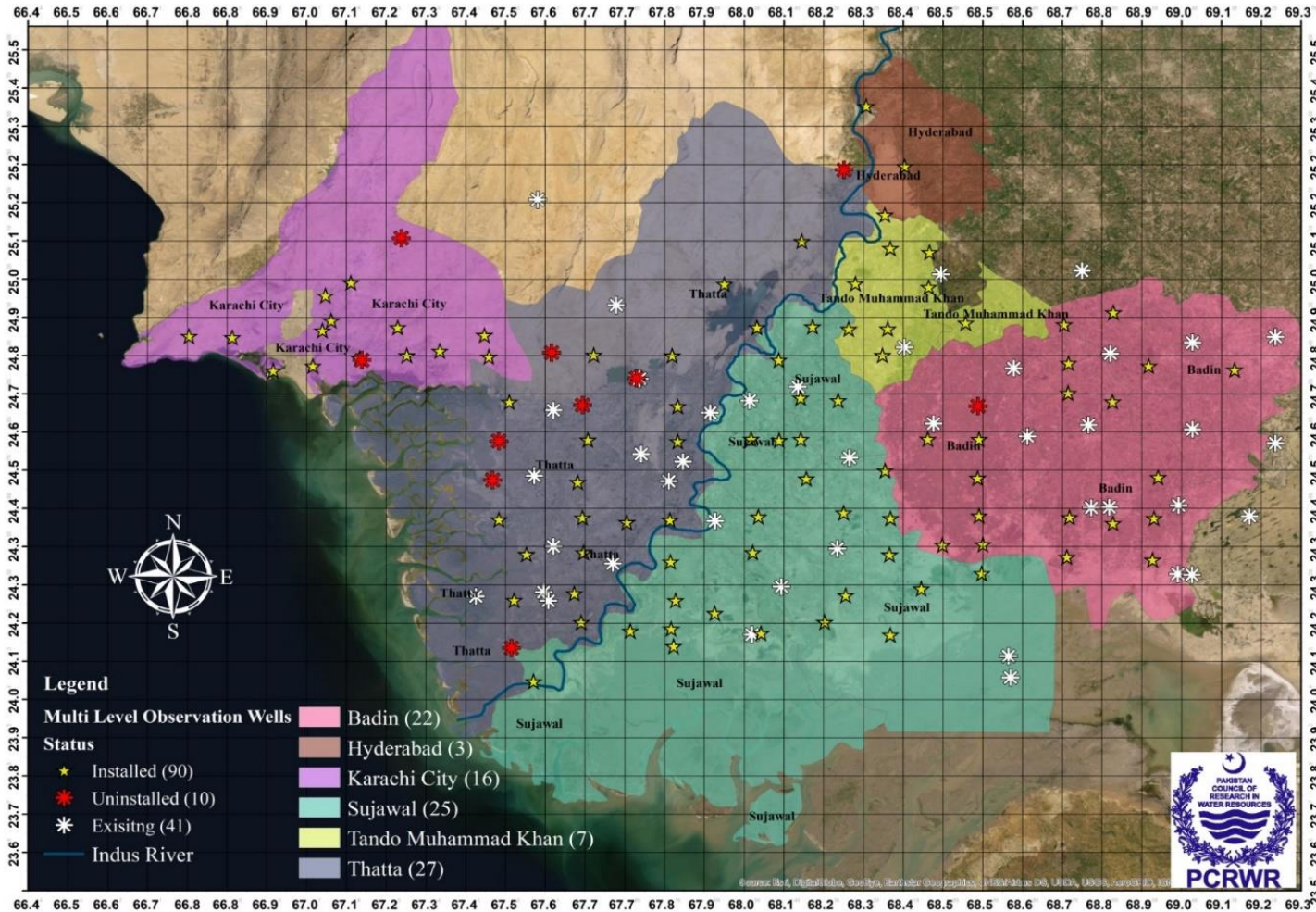
Image © 2016 DigitalGlobe

Google Earth

Imagery Date: 8/21/2013 25°27'23.14" N 66°33'43.32" E elev 15 ft eye alt 1836 ft



# Installation of Piezometers (MLOWs) upto December, 2021









# Soil and Water Sampling During Installation of MLOWs

Piezo-meters Installed	Soil Samples Collected	Water Samples Collected	Remarks
90 Nos. (Sujawal, Thatta Tando Allayar, TMK, Badin, Hyderabad, Karachi)	552	350	Analysis in process





# Monitoring of WQ of Piezometers (MLOWs) New

**Aug.-Sep. 2021 = 154 Samples**

**Oct.- Nov.2021 = 167 Samples**

**Jan.- Feb.2022 = 320 Samples      Total= 641**

**Including DWT measurement**

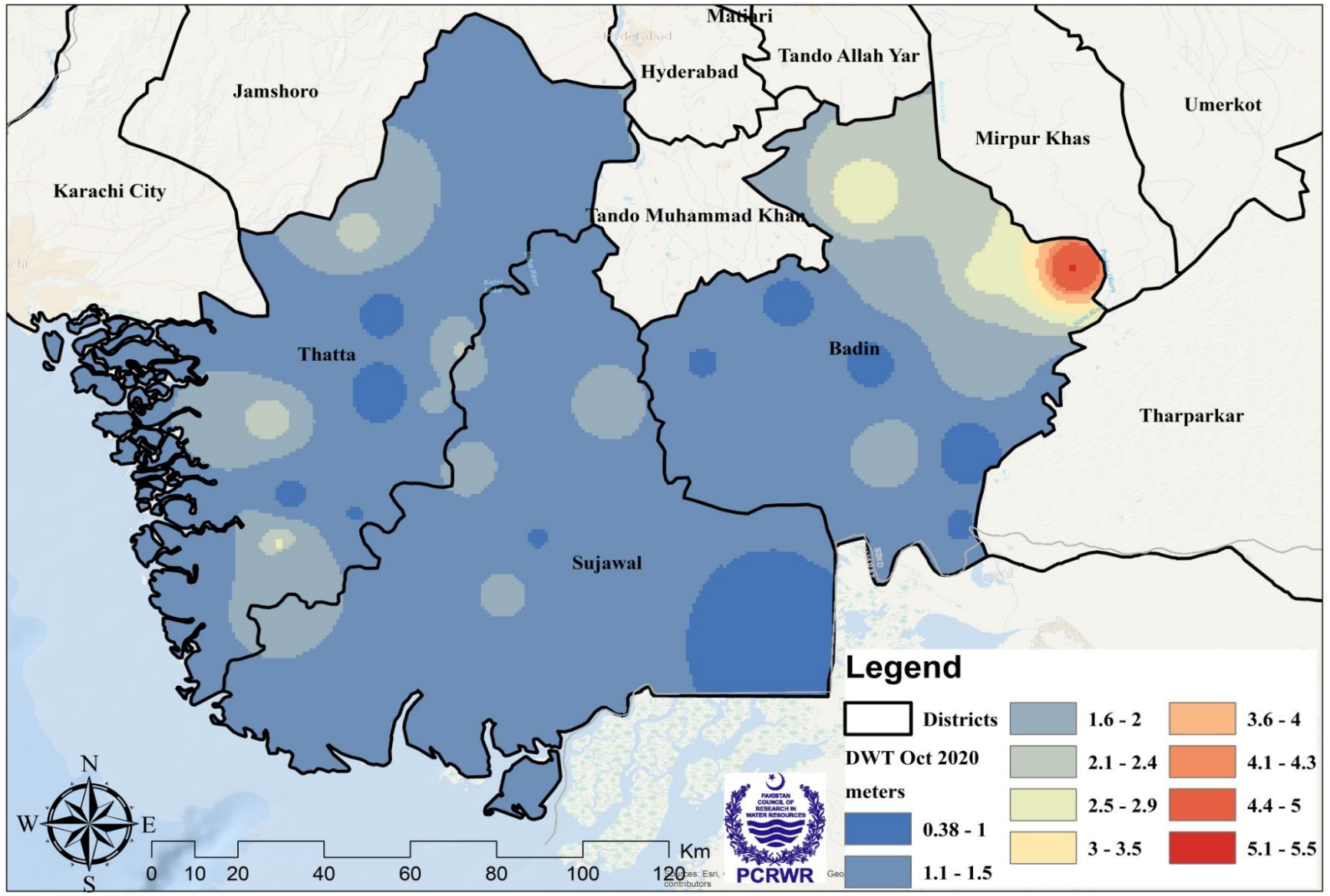




# Purchase & Training on LS2 Terra meter

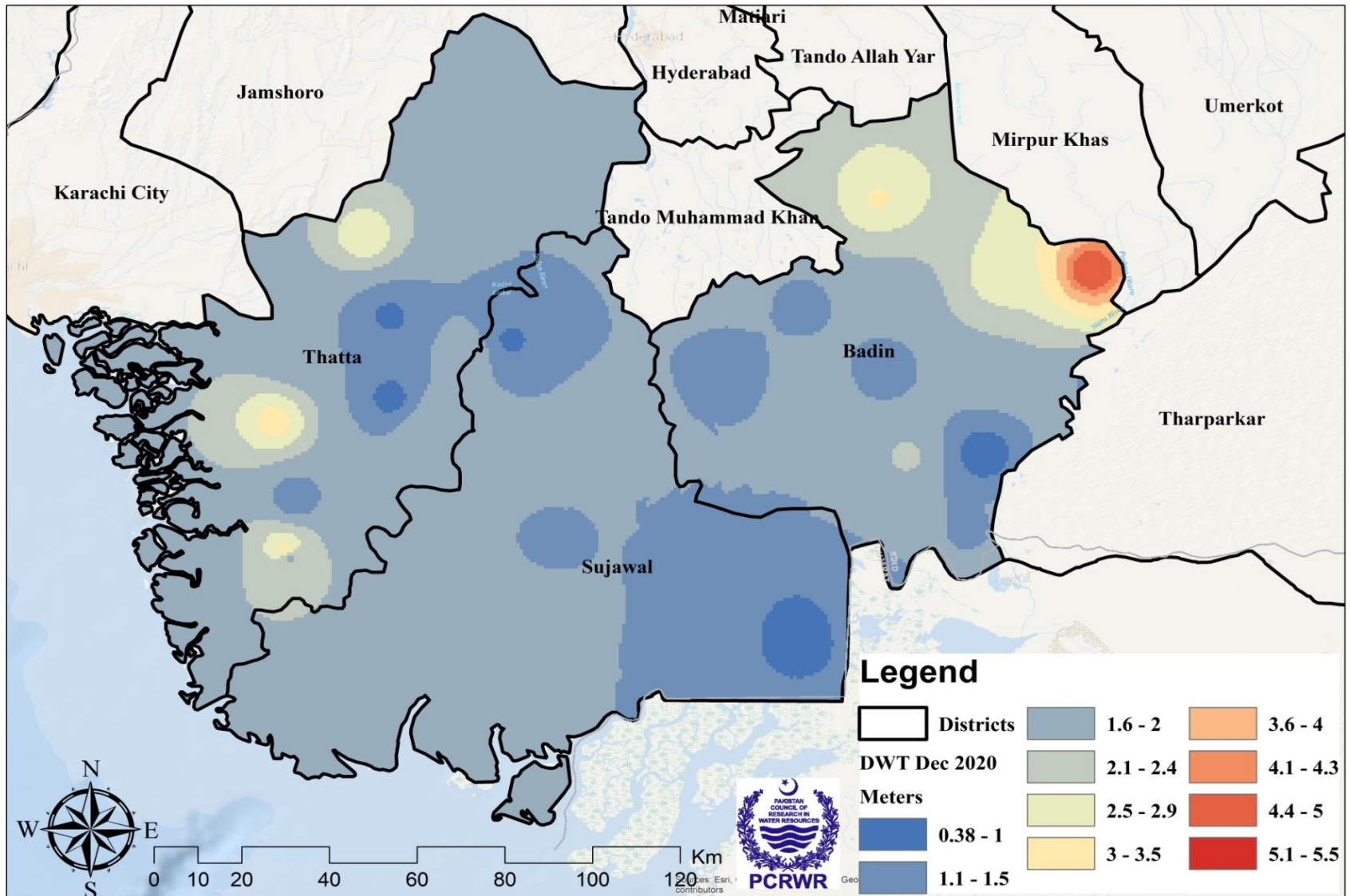


# Depth to Water Table (DWT) Measurement (Sept-October 2020)

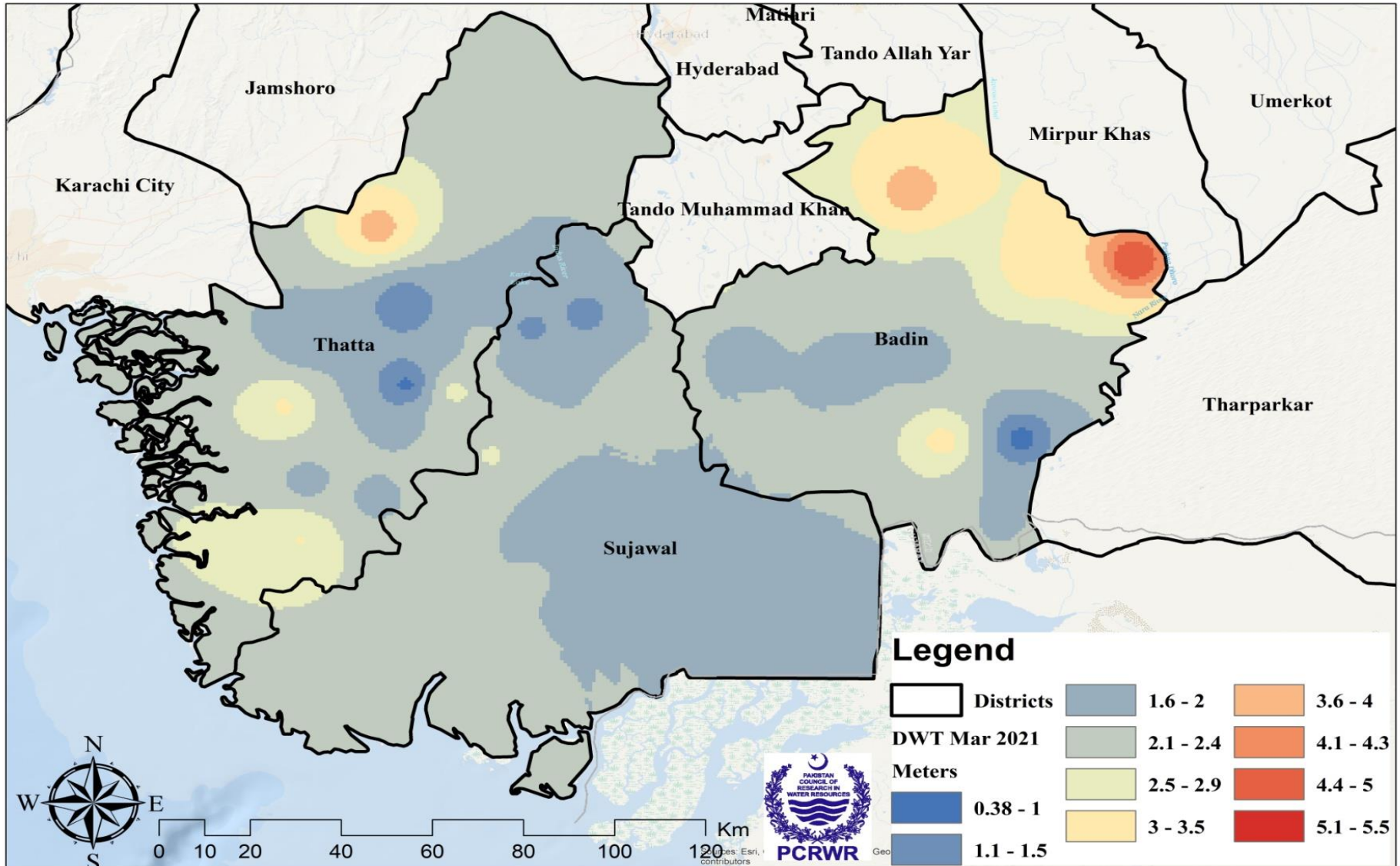




# Depth to Water Table (DWT) Measurement (November-December 2020)

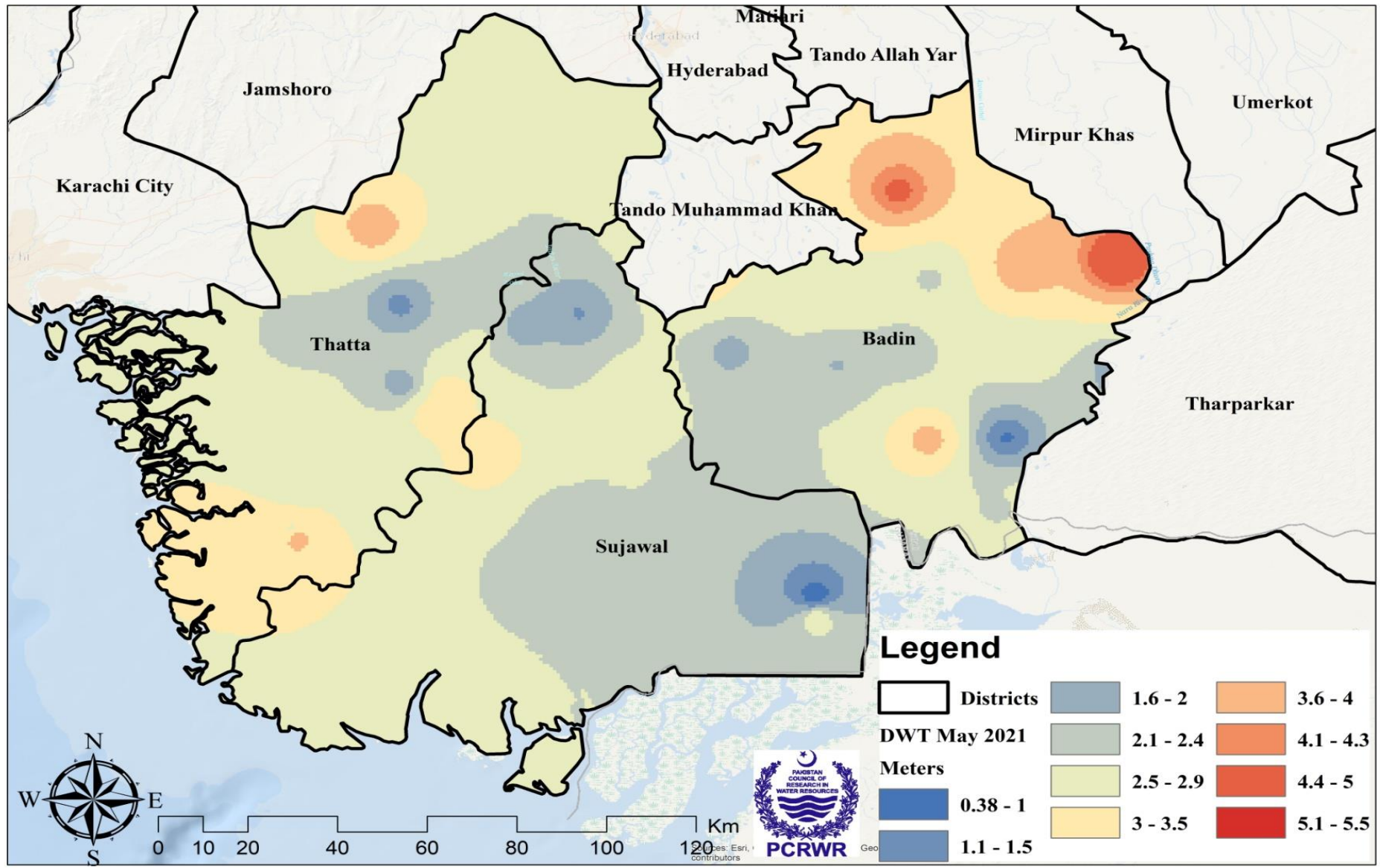


# Depth to Water Table (DWT) Measurement (Feb-March 2021)



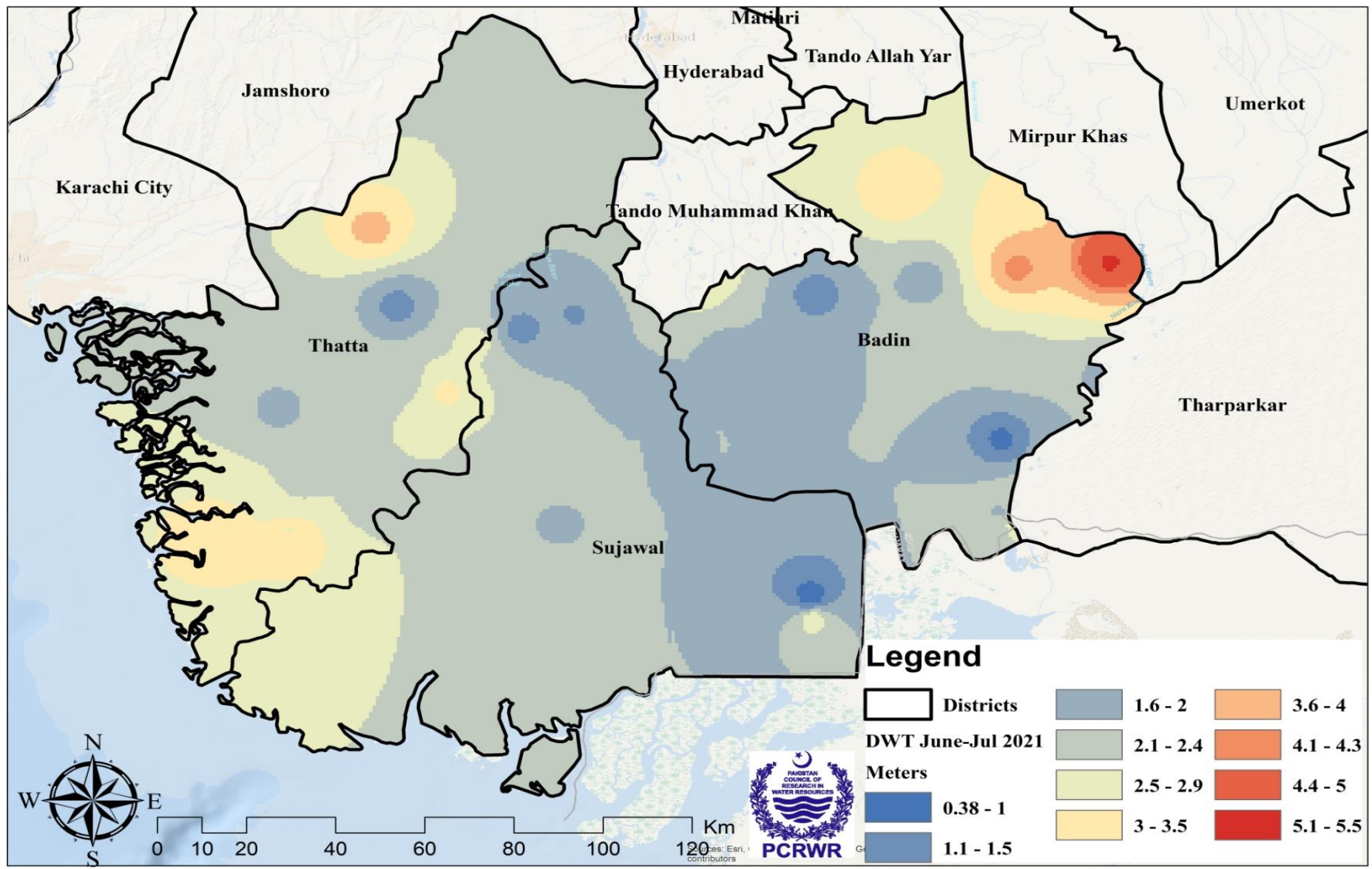


# Depth to Water Table (DWT) Measurement (April-May 2021)

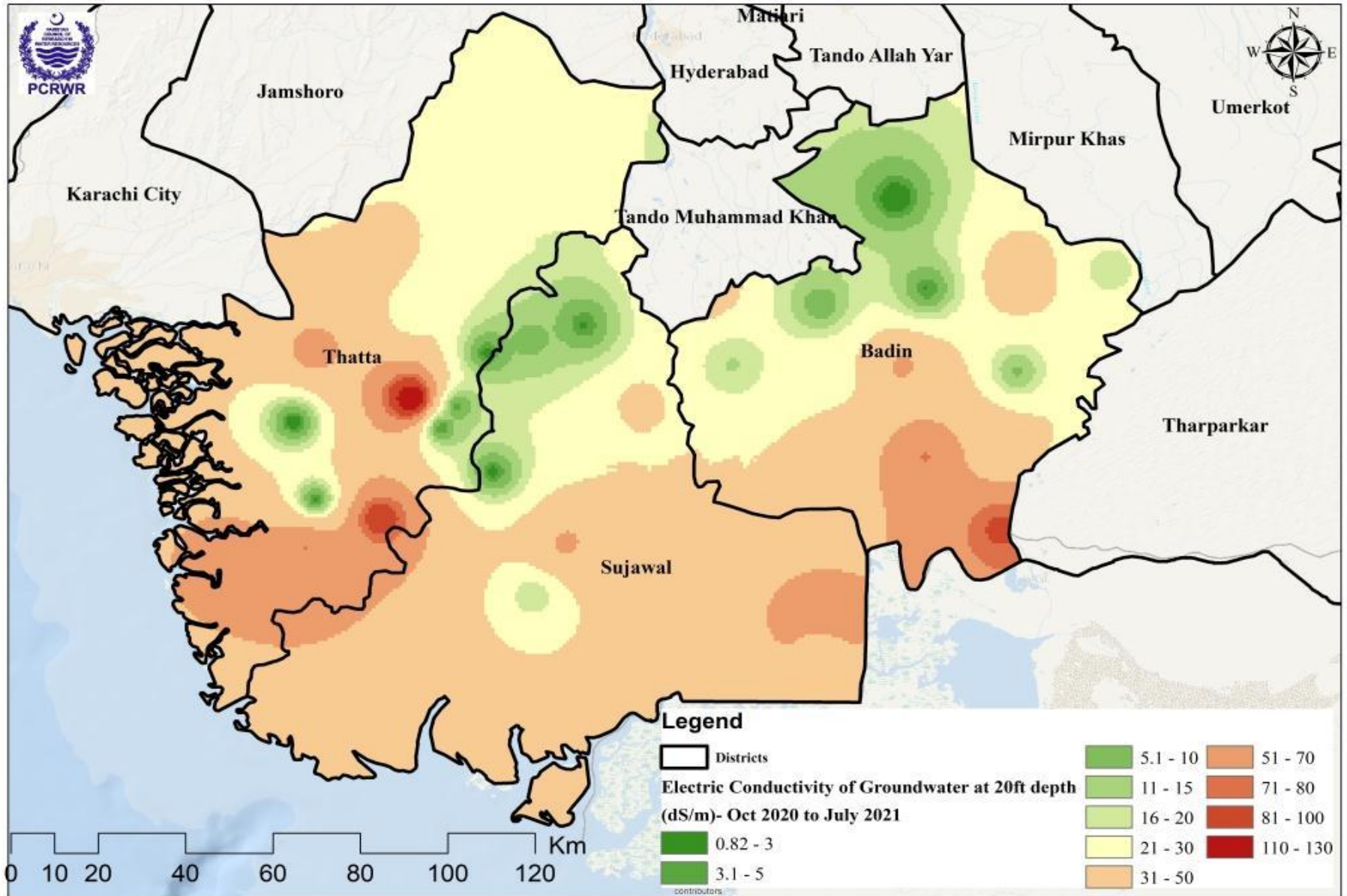




# Depth to Water Table (DWT) Measurement (June-July 2021)

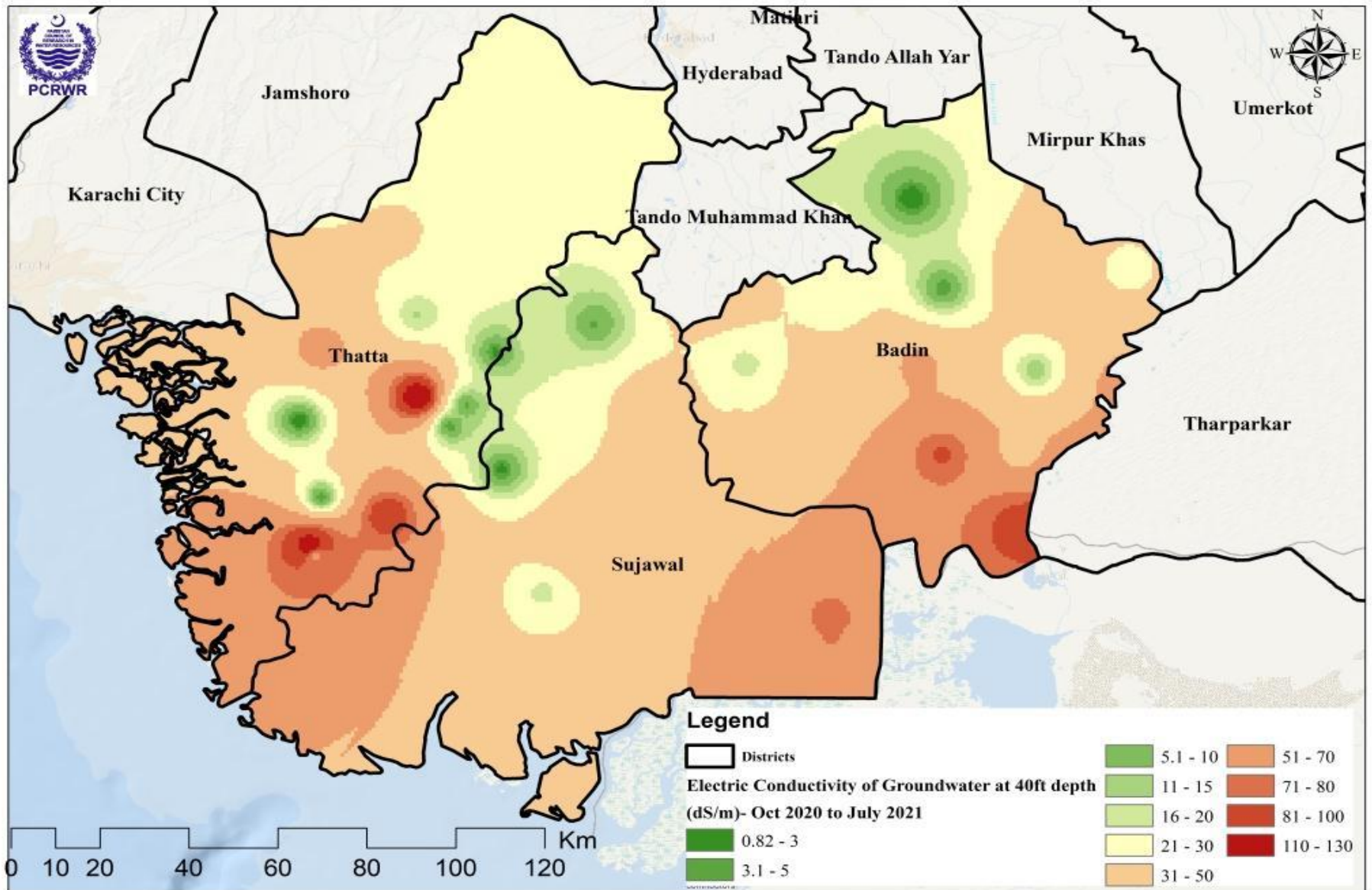


# Measurement of Electric Conductivity (dS/m) at 20ft Depth (October 2020 to July 2021)



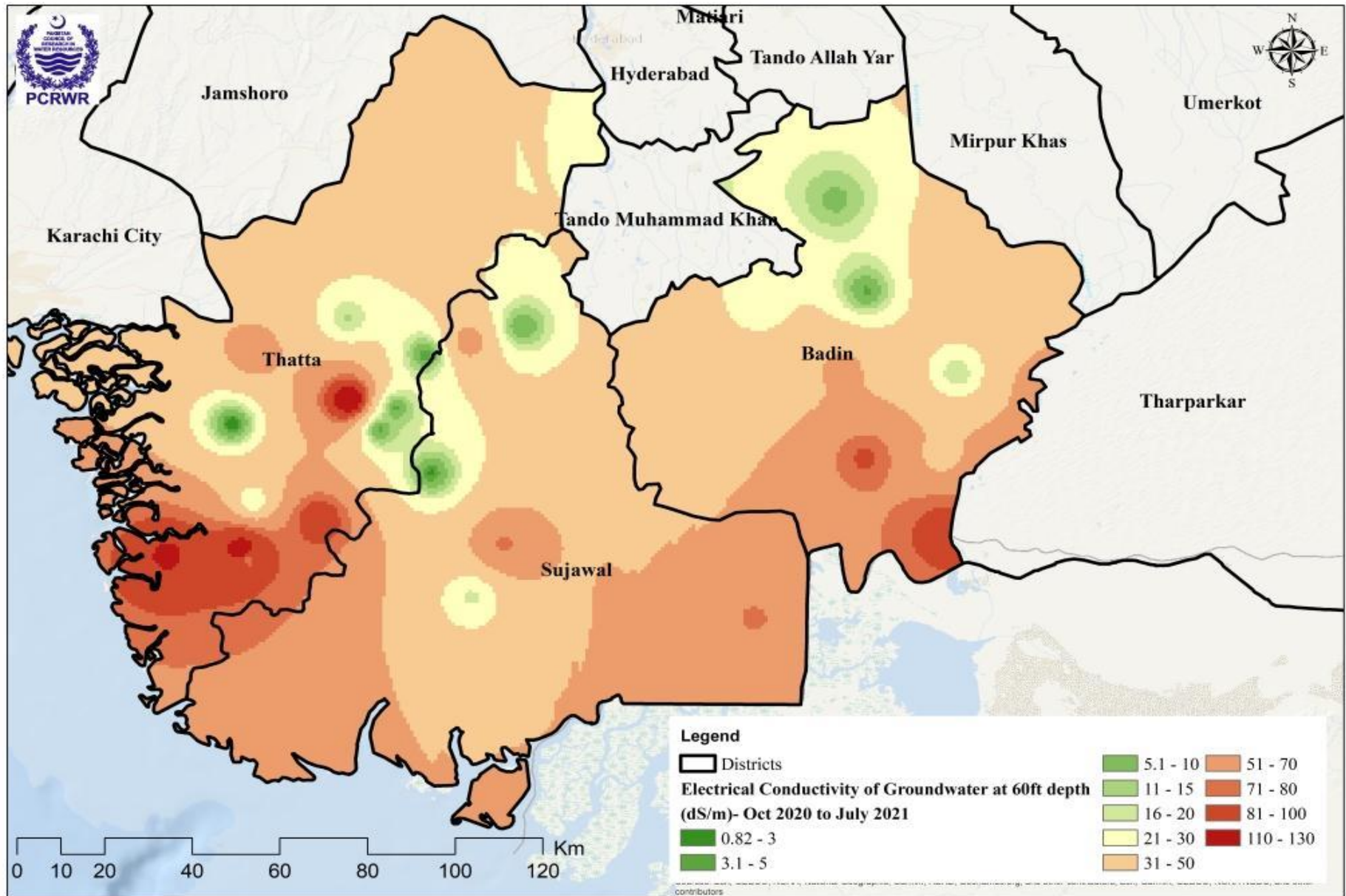


# Measurement of Electric Conductivity (dS/m) at 40ft Depth (October 2020 to July 2021)

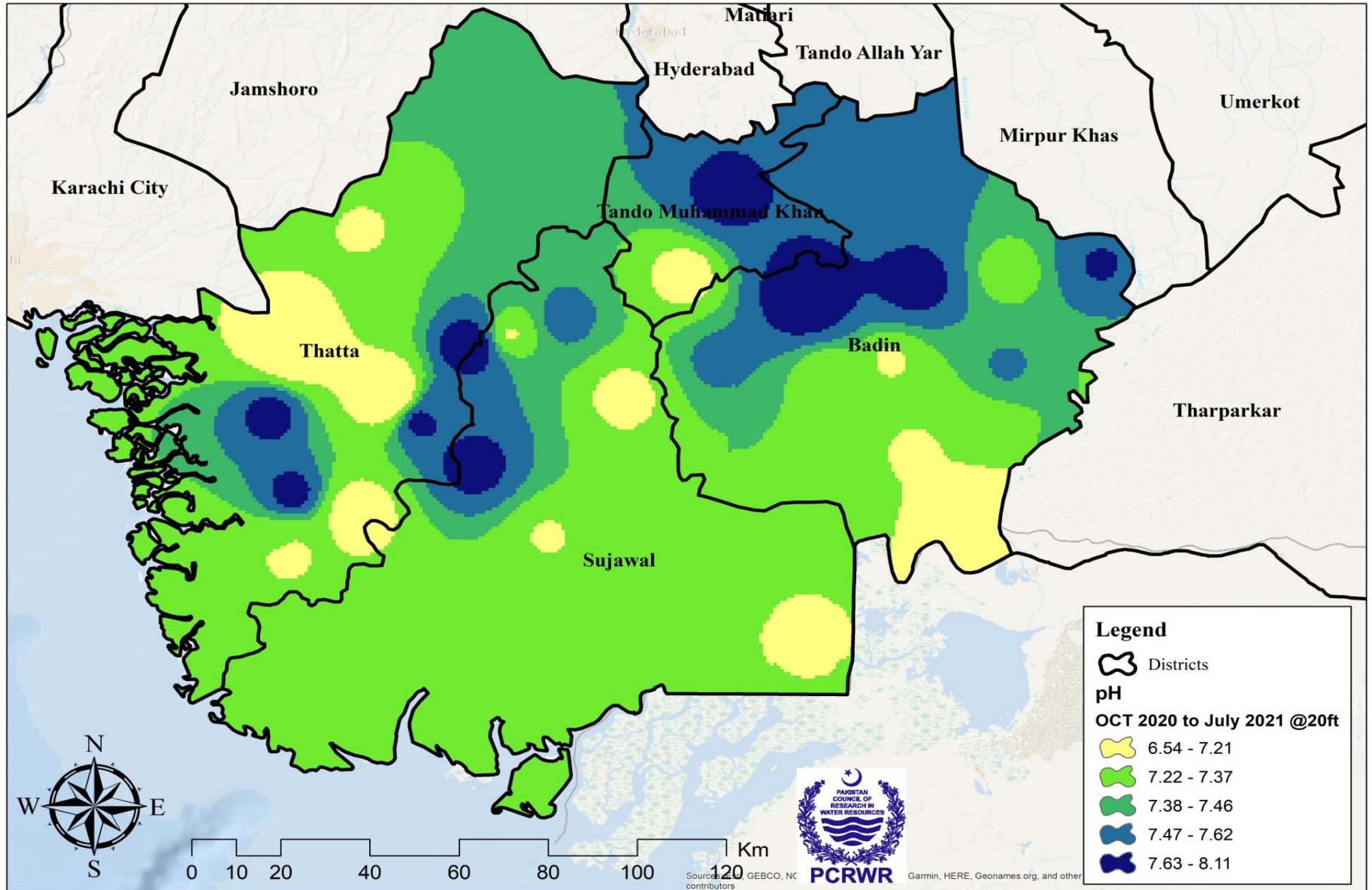




# Measurement of Electric Conductivity (dS/m) at 60ft Depth (October 2020 to July 2021)

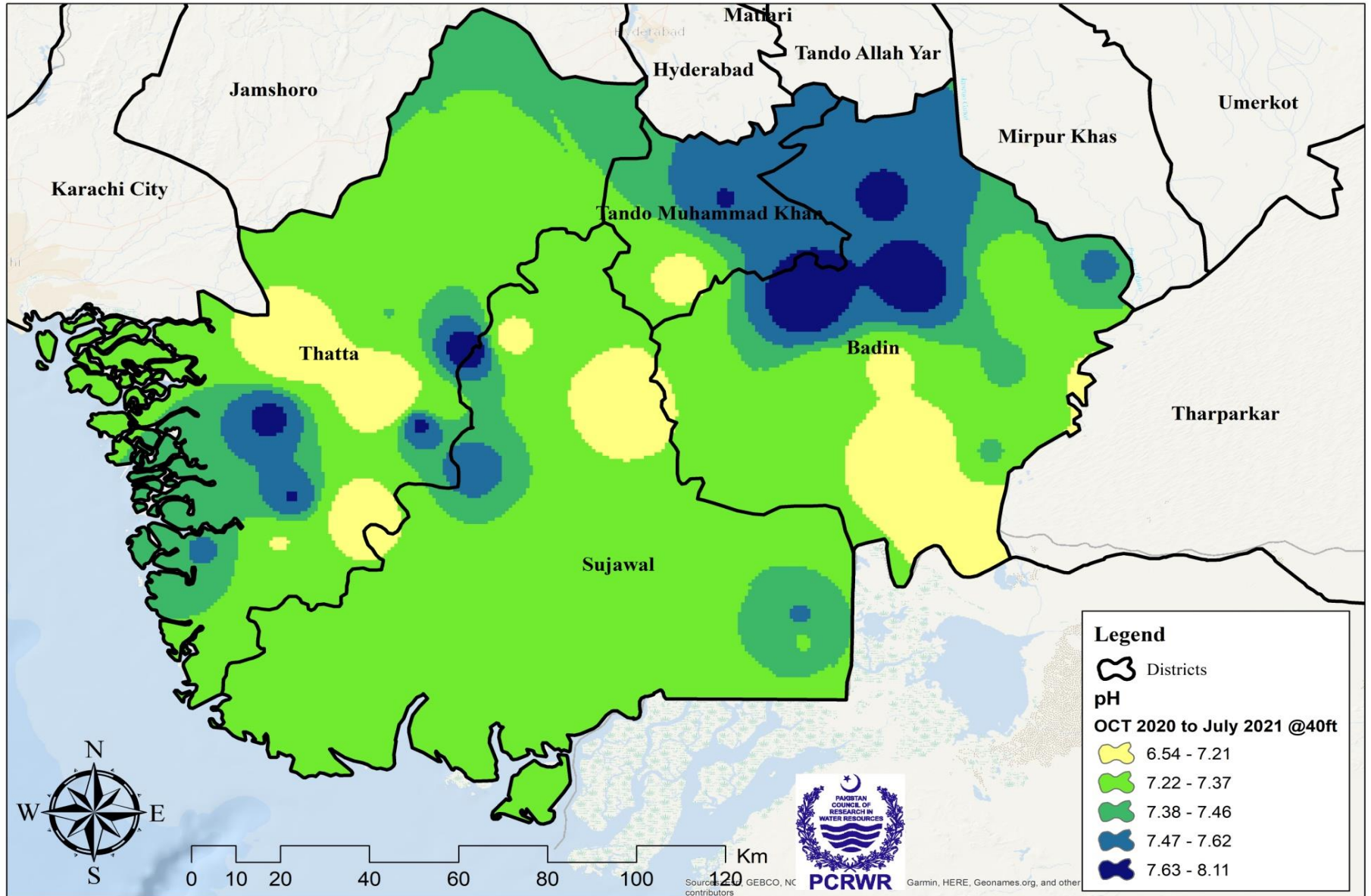


# Measurement of pH Value at 20ft Depth (Oct-2020 to July 2021)



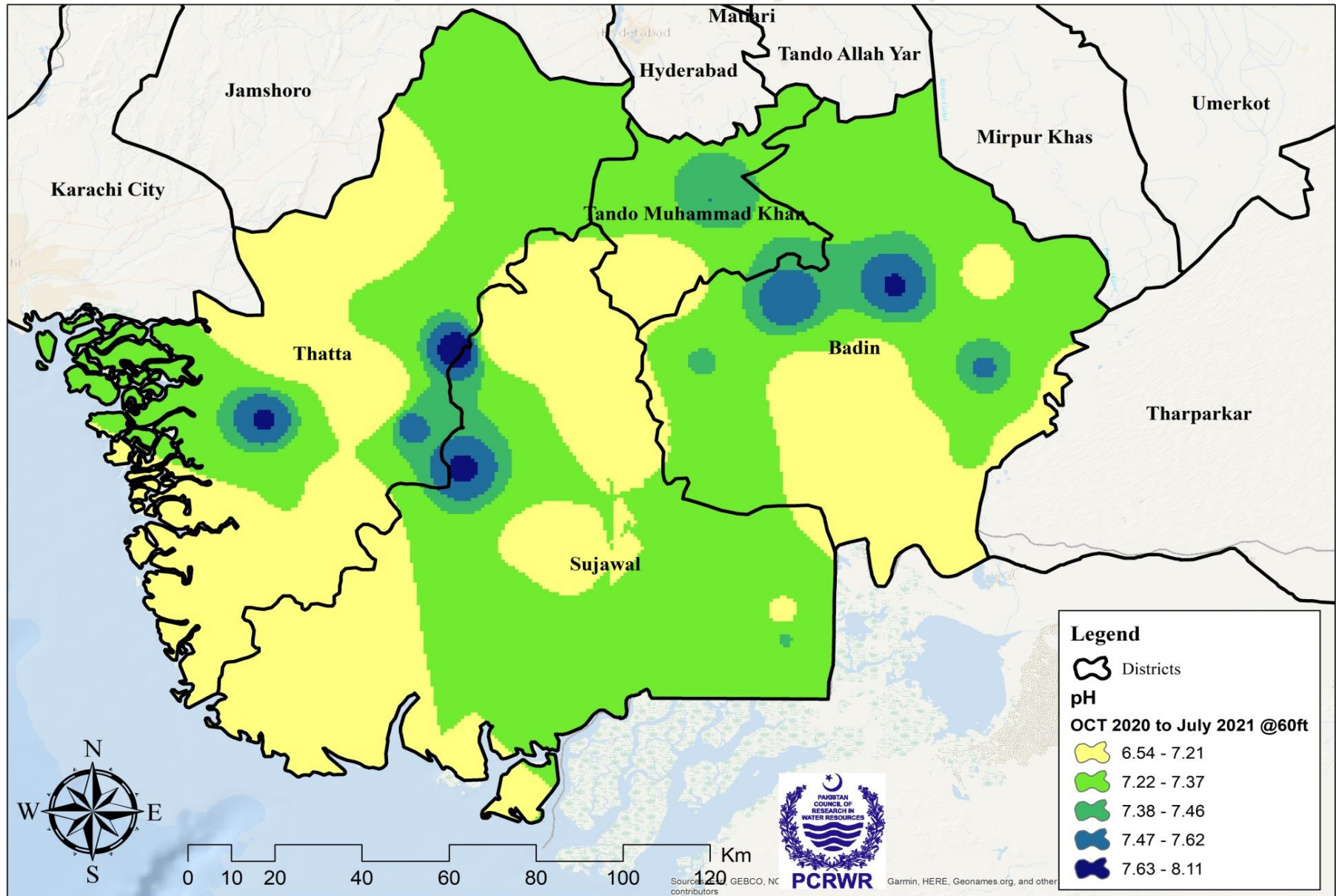


# Measurement of pH Value at 40ft Depth (Oct-2020 to July 2021)





# Measurement of pH Value at 60ft Depth (Oct-2020 to July 2021)



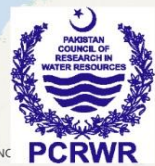
**Legend**

Districts

pH

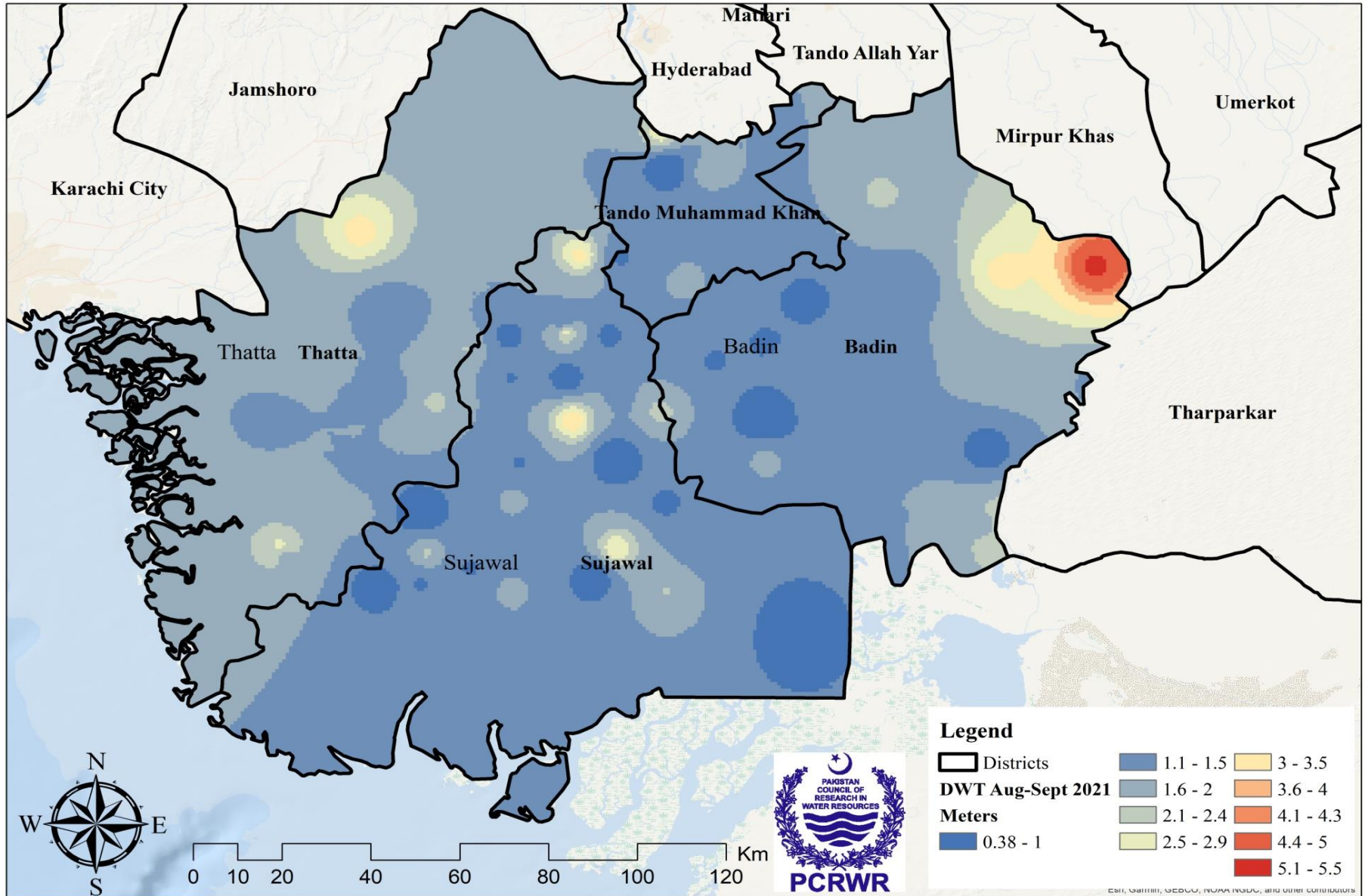
OCT 2020 to July 2021 @60ft

- 6.54 - 7.21
- 7.22 - 7.37
- 7.38 - 7.46
- 7.47 - 7.62
- 7.63 - 8.11



Source: GECBO, NC contributors  
Garmin, HERE, Geonames.org, and other

# Depth to Water Table (DWT) Measurement (August-Sept 2021) 52 MLOWs New







07/25/2015 11:59

**Thank you for your  
attention**

