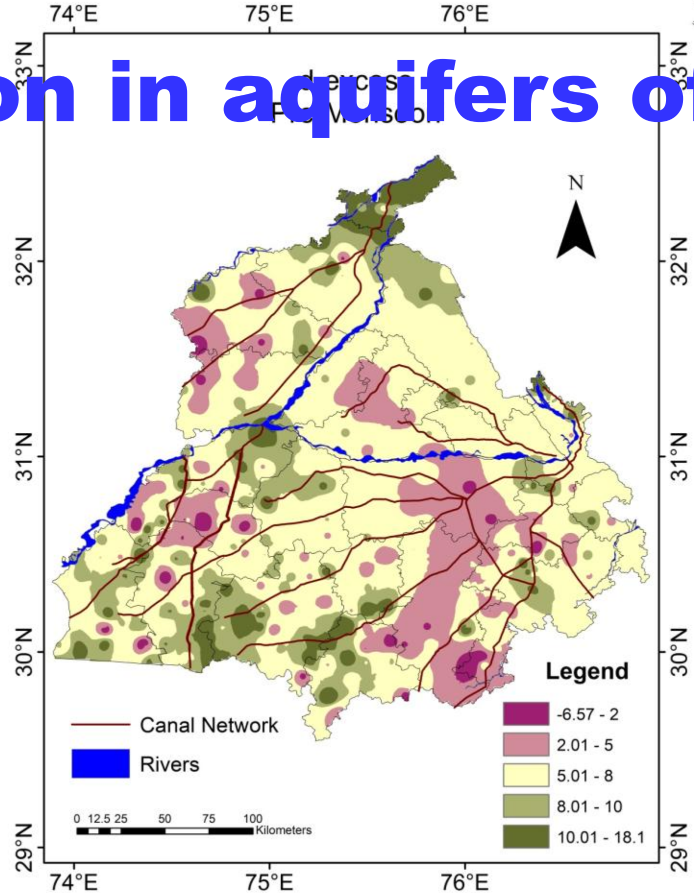
Case studies on groundwater salinity

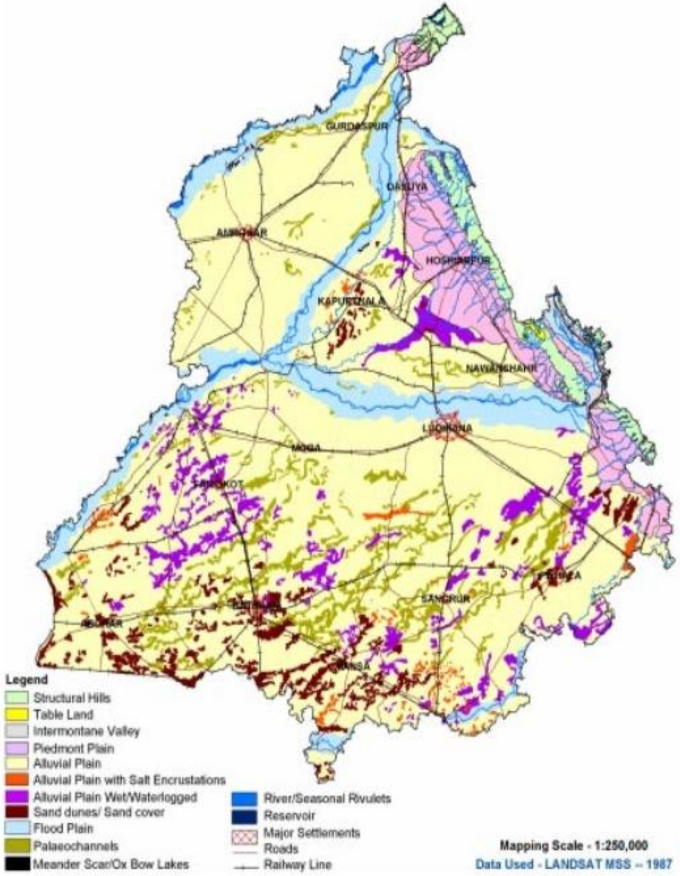
- Dr. Gopal Krishan, Scientist – ‘C’
  National Institute of Hydrology, Roorkee
- Email: drgopal.krishan@gmail.com

Expansion of salinization in aquifers of Punjab



Sponsored by: Punjab State Farmers and Farm Workers Commission

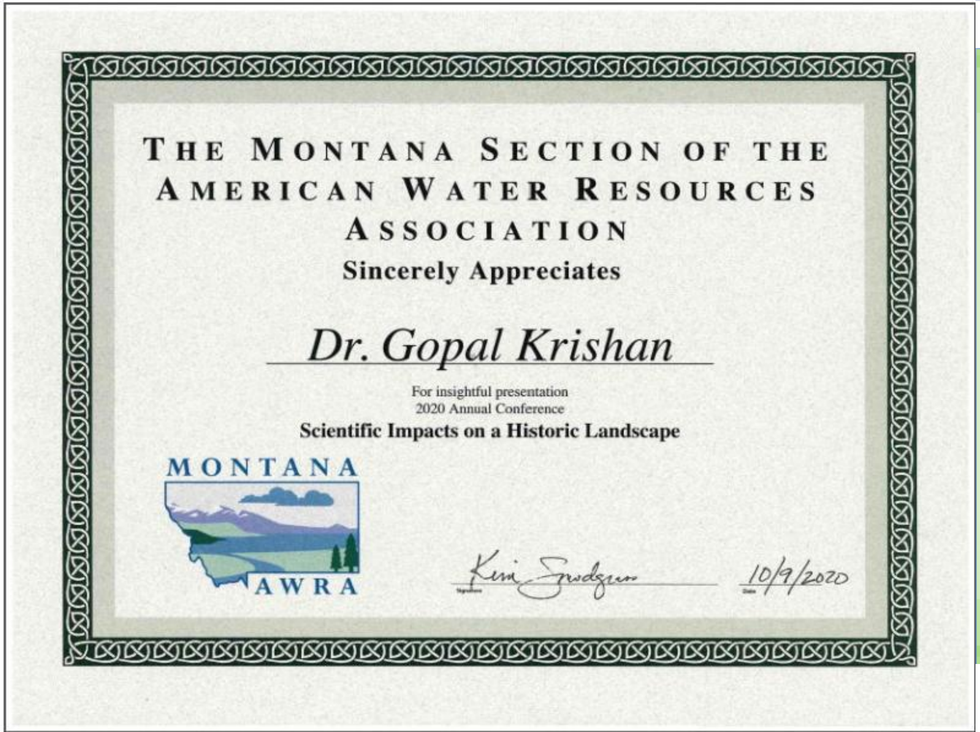
STUDY AREA

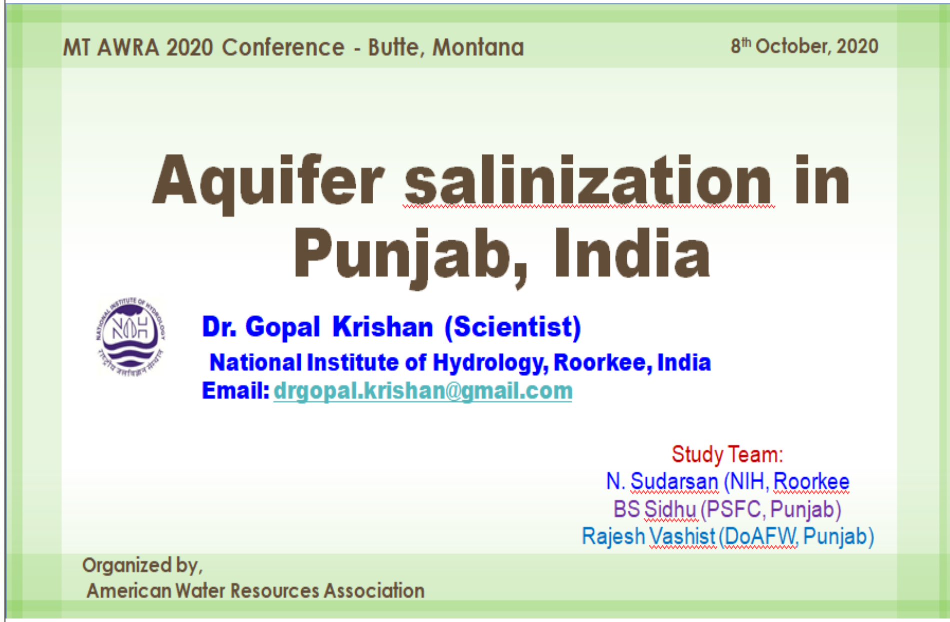


Prepared by: Punjab Remote Sensing Centre, Ludhiana

- **Punjab comprising 1.5% (50,362 sq. km) area of the country contributing 40–50% rice & 60–65% wheat to the central pool since last 3 decades.**
- **3 perennial rivers : Satluj, Beas & Ravi**
- **1 seasonal river: Ghaggar.**
- **Water potential all rivers : 14.54 Million Acre Feet (MAF) managed through well-organized canal irrigation system.**
- **However, the available surface water resources of the State are fully committed even though unable to meet further demand of water in irrigation for agriculture which increases the pressure on groundwater resources**

Sr. no	Activity	% Progress in the activity till date
7	Publications 1.	Krishan, Gopal, Sudarsan, N, Sidhu, BS, Vasisth, Rajesh. 2020. Aquifer salinization in Punjab, India. In: Proceedings for Scientific Impacts on a Historic Landscape American Water Resources Association Montana Section 2020 Conference Butte, Montana October 5 - October 9, 2020 (certificate of appreciation)





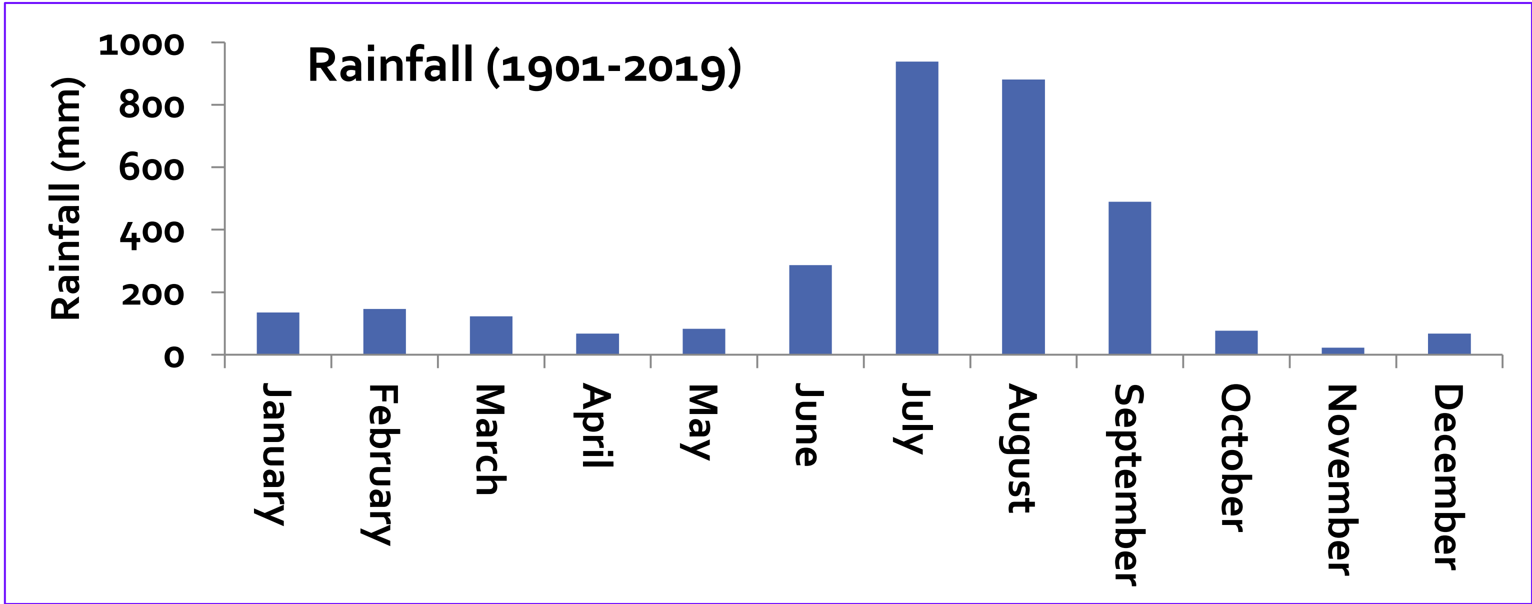
1. Generate groundwater level scenarios based on historical data

Data Collected/Analysed/ Maps Prepared

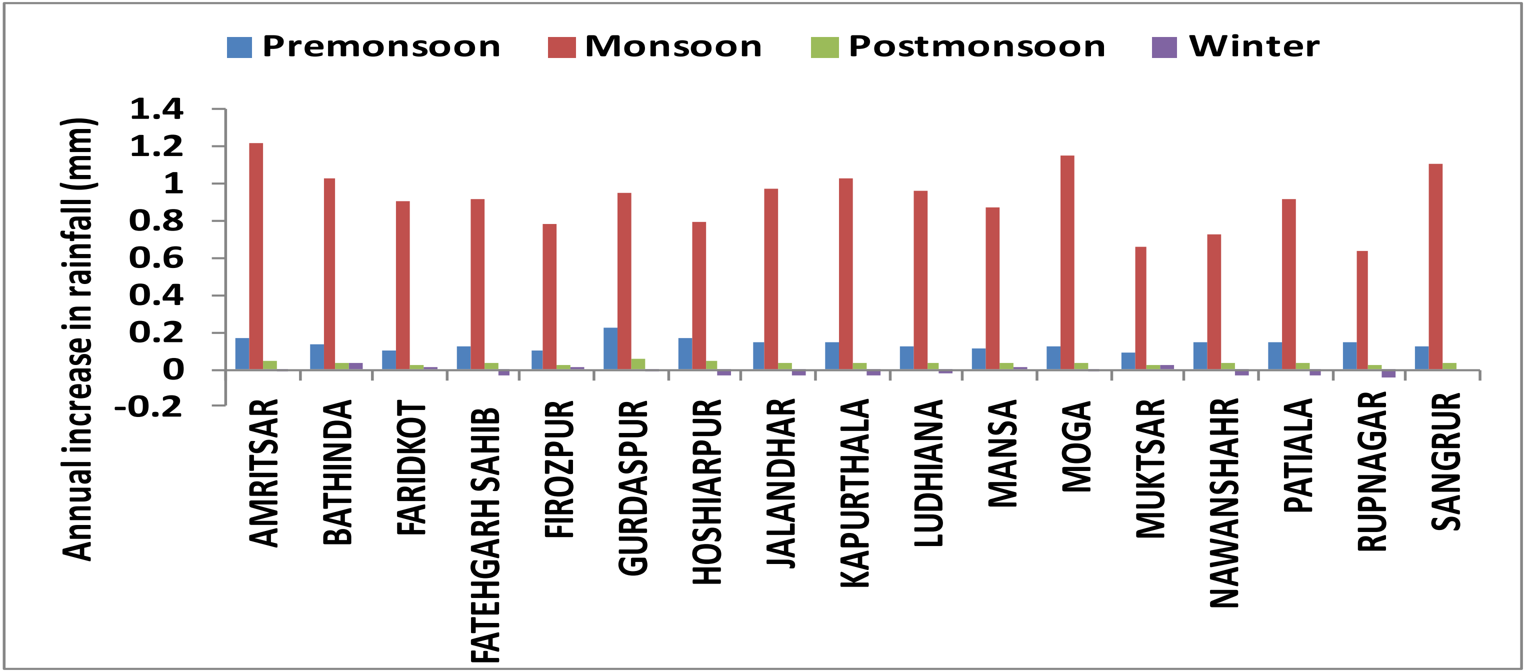
- ***Rainfall variations***
- ***Digital Elevation Model (DEM)***
- ***Soils***
- ***Geomorphology/Lithology/Aquifer systems***
- ***Land use/Land cover maps***
- ***Groundwater level variation***

Rainfall (Month wise variations)

80% during July to September



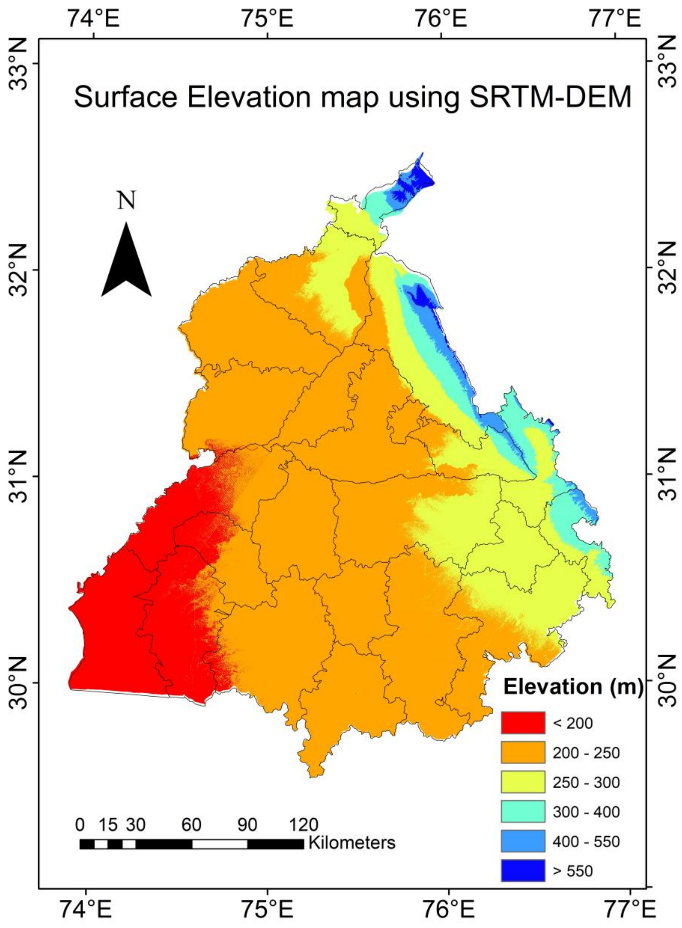
Rainfall trend analysis



Trend detection analysis of rainfall of Punjab has indicated an increasing rainfall trends in annual, monsoon, pre-monsoon and post-monsoon seasons.

Winter rainfall is found decreasing in 11 districts. In future, the variability of rainfall is likely to increase in Punjab. Rainfall has a rising trend at some districts in south-west Punjab namely Bhatinda & Moga which currently receive low annual rainfall. Krishan et al., 2015

DEM

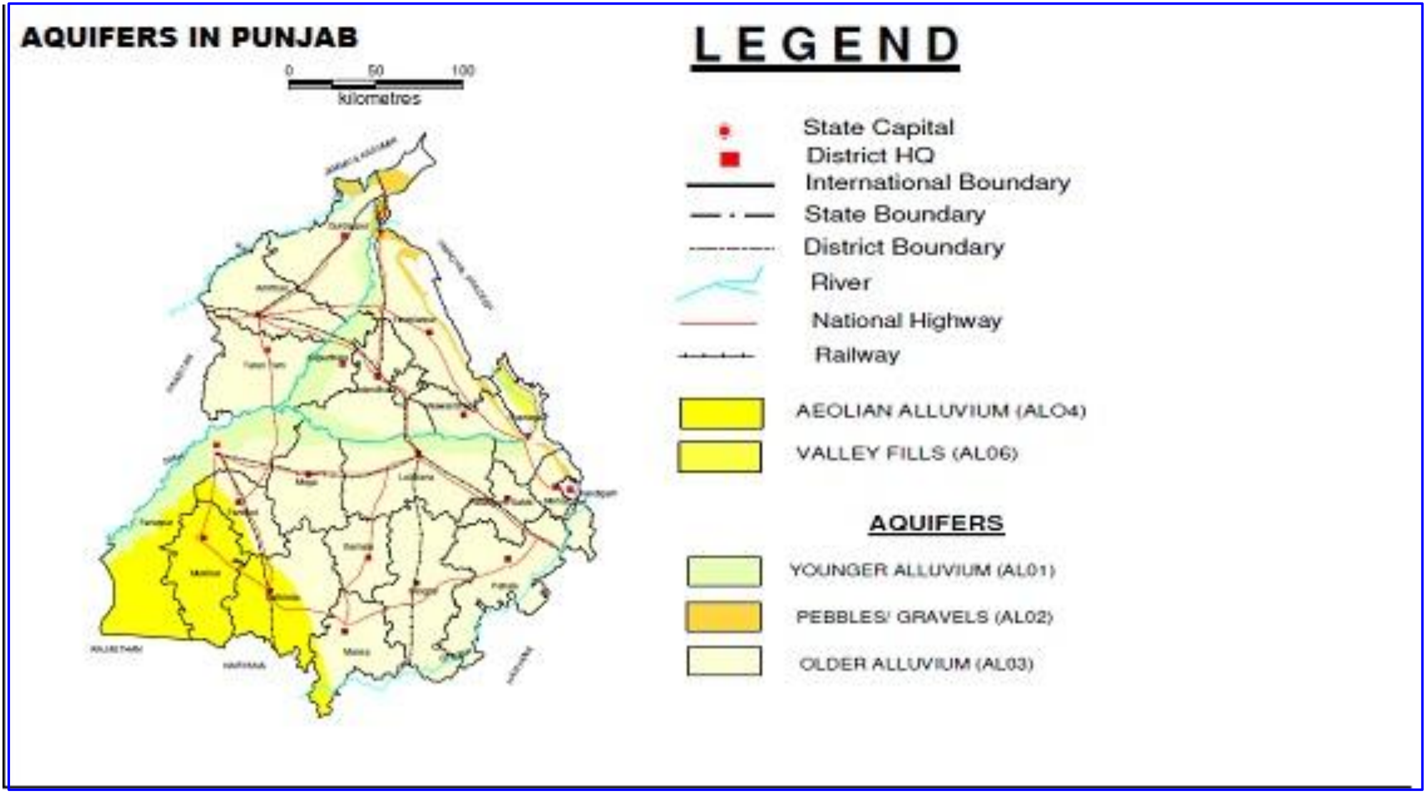


Punjab is an extensive alluvial plain gently sloping from about 650 metres above sea-level in the northeast and the north adjoining Himachal Pradesh and Jammu and Kashmir to about 180 metres in the southwest.

The south-western fringe of the region is desertic and undulating, but has gradually been becoming level with the extension of cultivation and irrigation.

DEM downloaded from USGS Earth Explorer (https://earthexplorer.usgs.gov/)
Mapped using ArcGIS 10.4

Aquifer systems

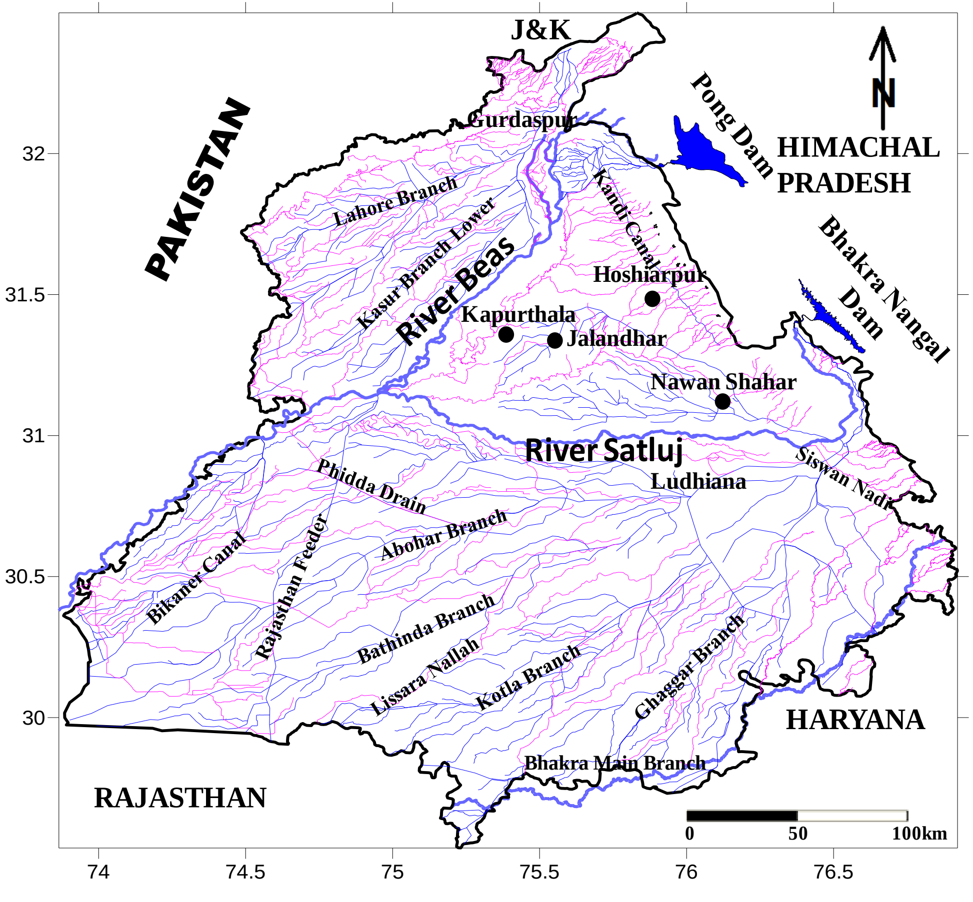


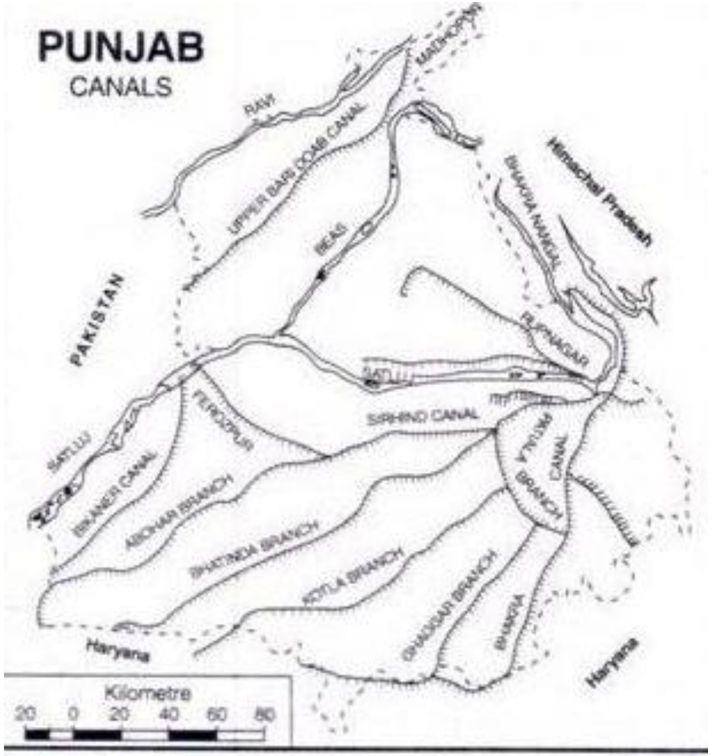
In general single and multiple aquifers systems have been identified

In major part of the state multiple aquifer system exists

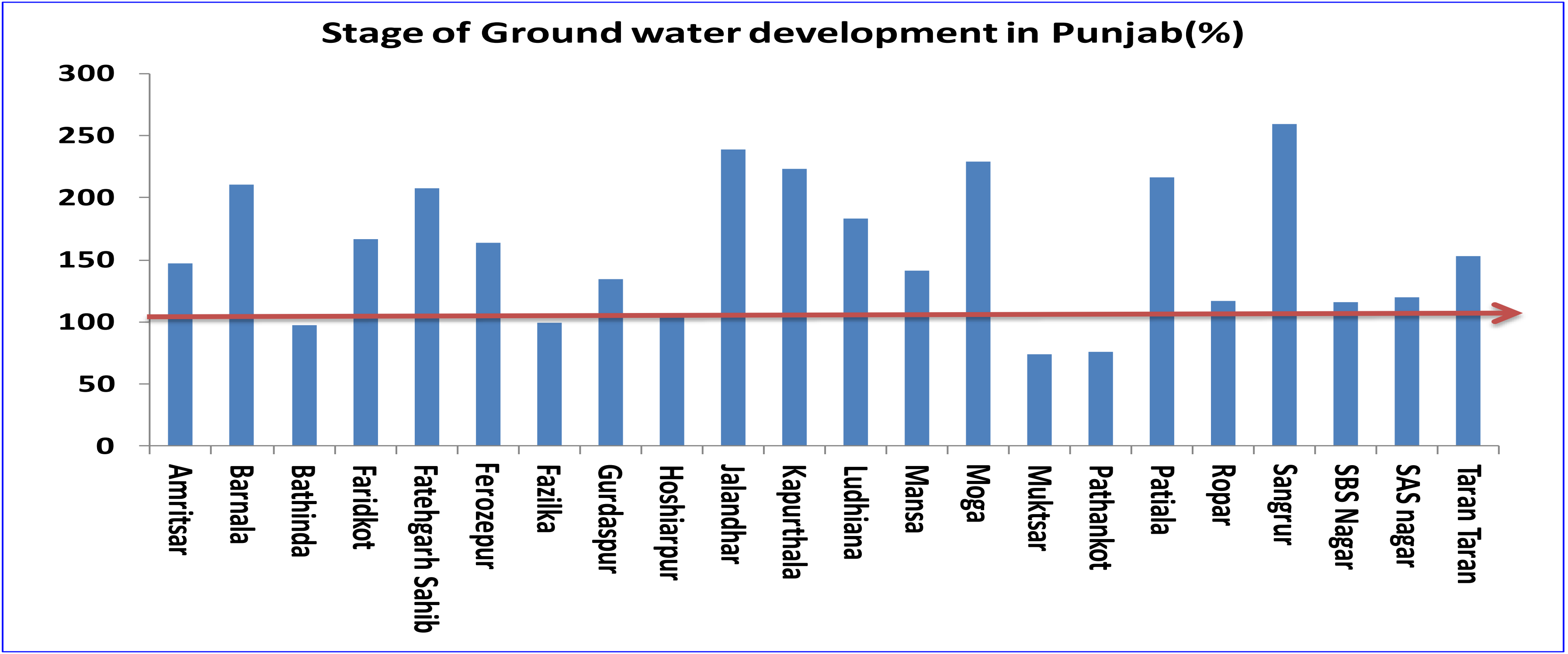
Source: CGWB

Punjab Drainage



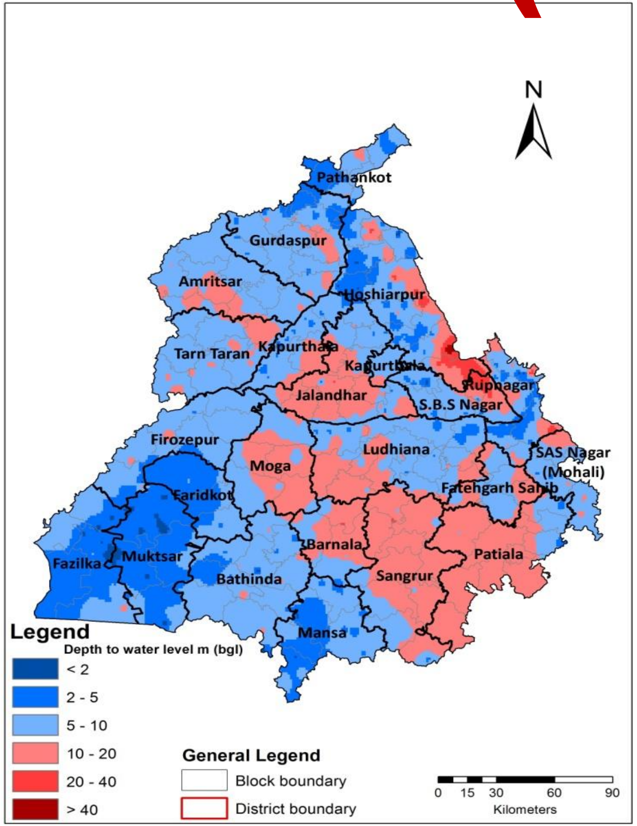


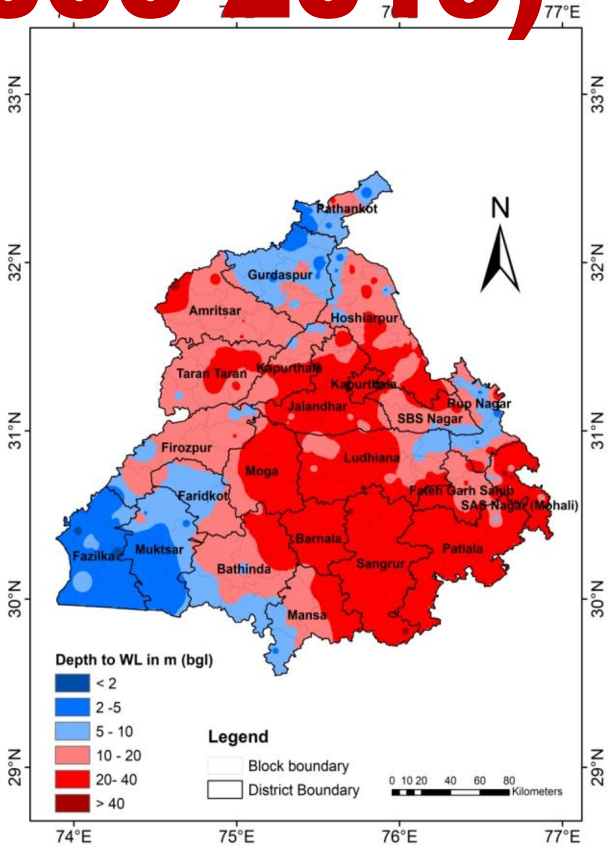
Stage of groundwater development



Source: CGWB

Groundwater level spatial variation (2000-2019)





northeastern,

eastern,

central and

north western and

southern

Source: DoA, Punjab

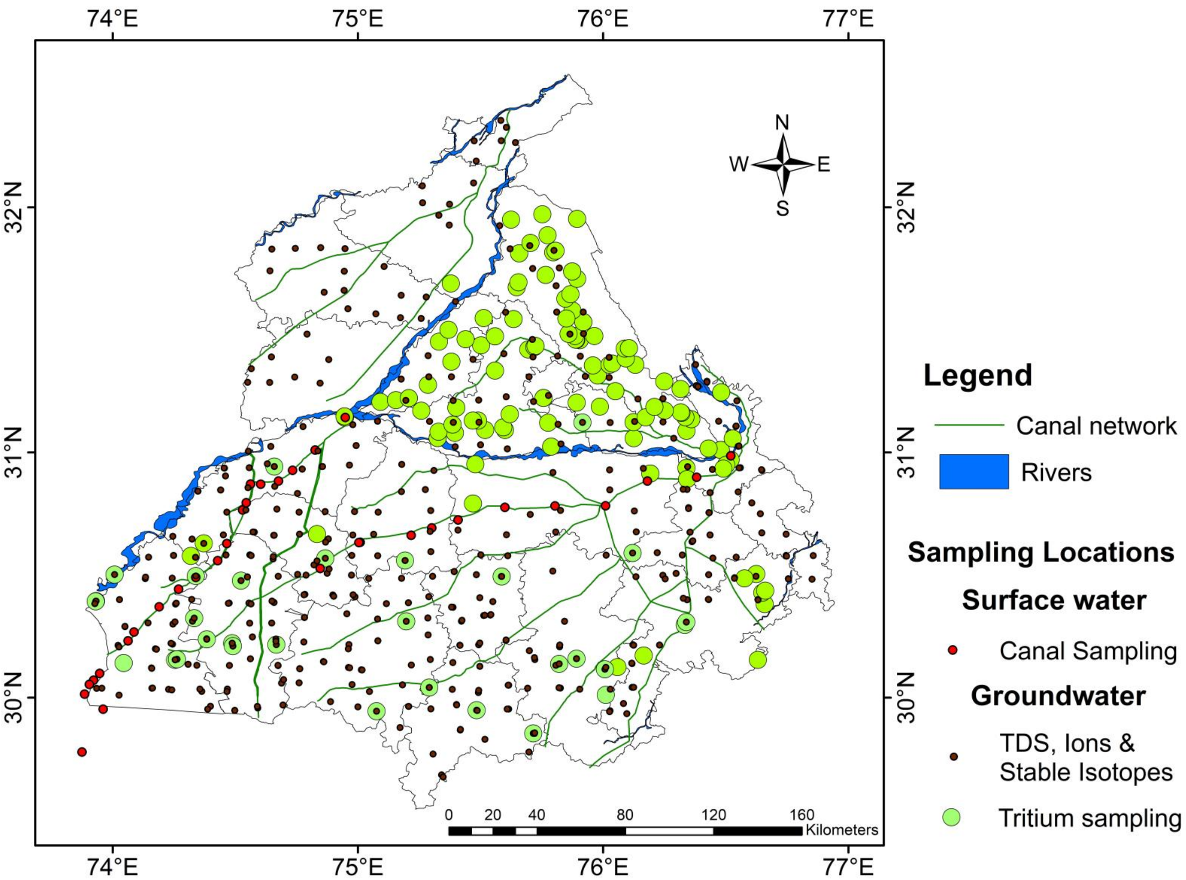
2. Assess the extent of water logged and groundwater saline zone at various aquifer depths,

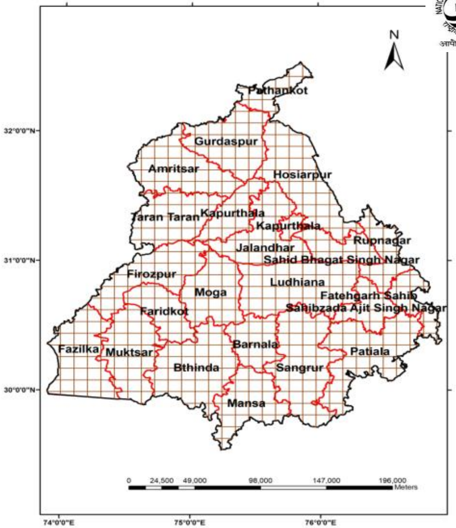
3. Investigate and identify the cause of salinity problem and its expansion in the area,

Methodology/ Data

- ***Ions distribution***
- ***Hydro-geochemical processes and indicators***
- ***Isotope characterization***

Analytical Results

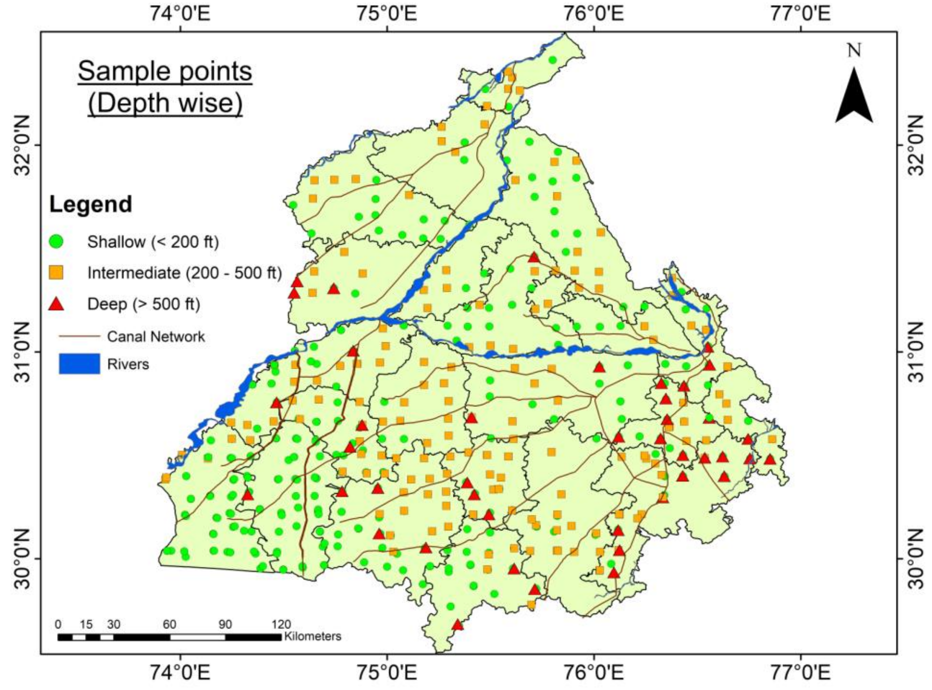


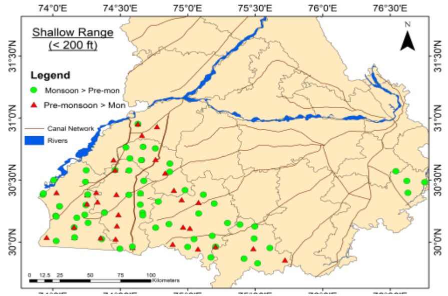


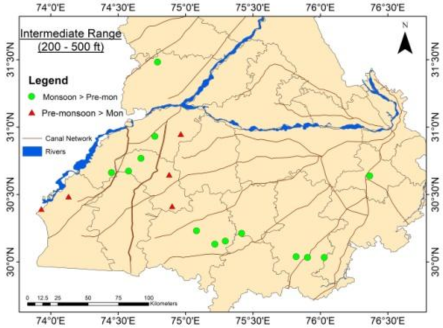
Entire state was divided into $10x10$ km^2 grid and groundwater sampling was carried out in each grid

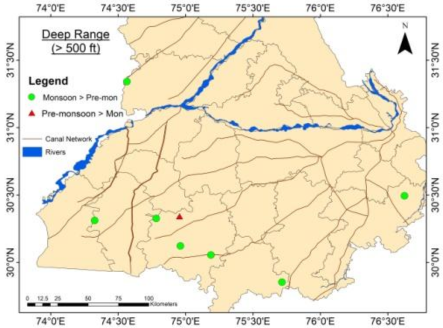
Canal sampling at an interval of 20 km

Groundwater sampling









Ions concentrations

mg/l

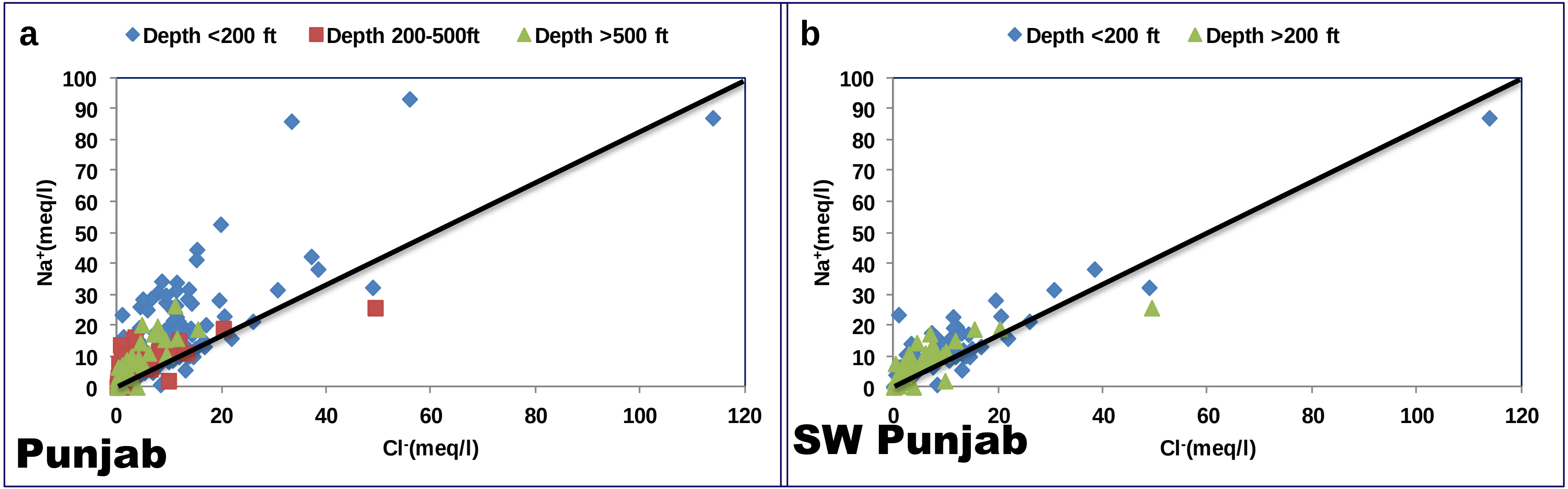
	Ca^{2+}			Mg^{2+}			Na^{+}			K^{+}		
	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
Min	5.2	7.8	10.3	1.0	3.6	3.7	1.0	2.5	13.6	0.5	0.7	0.9
Max	297.4	114.8	81.3	2145.4	88.5	86.4	2145.4	590.3	604.6	489.3	151.8	88.9
Mean	50.2	37.9	32.8	246.5	26.0	27.3	246.5	113.3	185.3	16.1	6.3	6.5

mg/l

	HCO_3^-			F^-			Cl^-			SO_4^{--}			NO_3^-		
	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3	D1	D2	D3
Min	108.0	55.3	114.3	0.1	0.02	0.1	2.2	1.9	13.6	5.7	2.1	5.0	0.6	0.3	0.8
Max	1234.7	711.3	619.7	9.5	7.9	4.7	4040.8	1750.1	604.6	4933.9	1814.4	1091.2	497.0	270.0	88.0
Mean	336.4	325.3	270.1	1.7	1.4	1.2	215.2	80.4	185.3	374.9	124.9	220.9	58.1	35.5	27.1

D1 = Depth < 200 ft, n= 270; D2= Depth 200-500 ft, n= 202; D3= Depth > 500 ft, n= 60

Hydrogeological processes



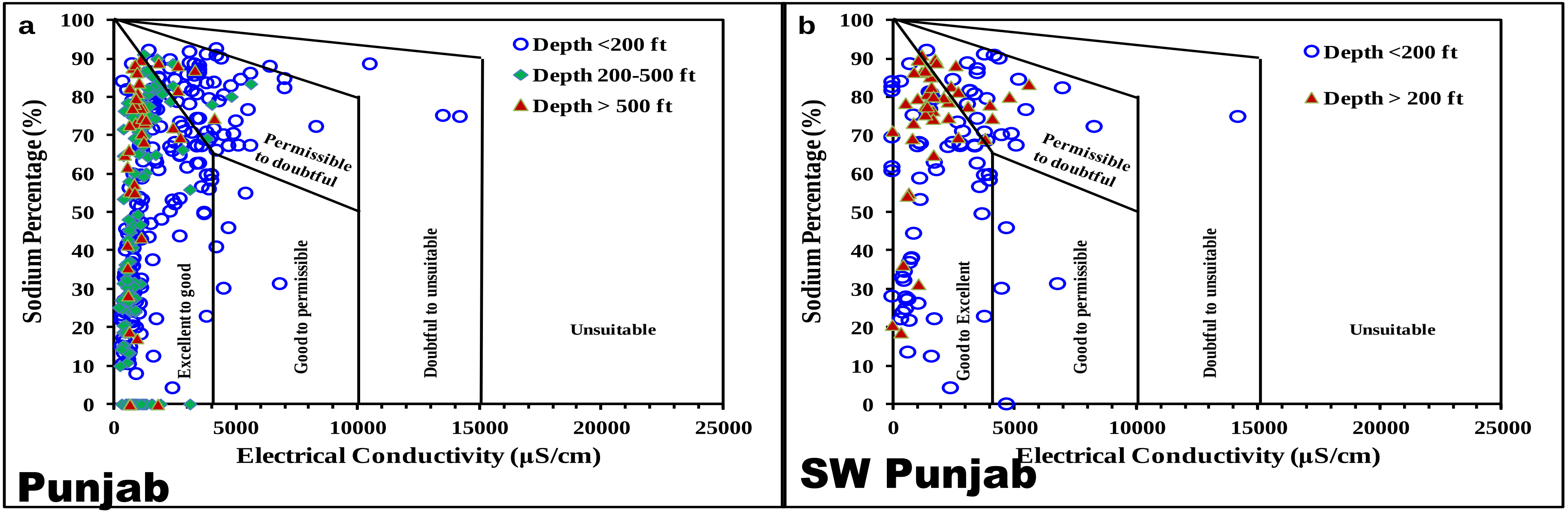
Na^+ vs Cl^- used to indicate the source of Na^+ ions in groundwater

•values close to the equiline suggest halite dissolution

•values >1, silicate weathering or cation exchange

silicate weathering along with Na+, high HCO^3- in groundwater

Hydrogeological processes

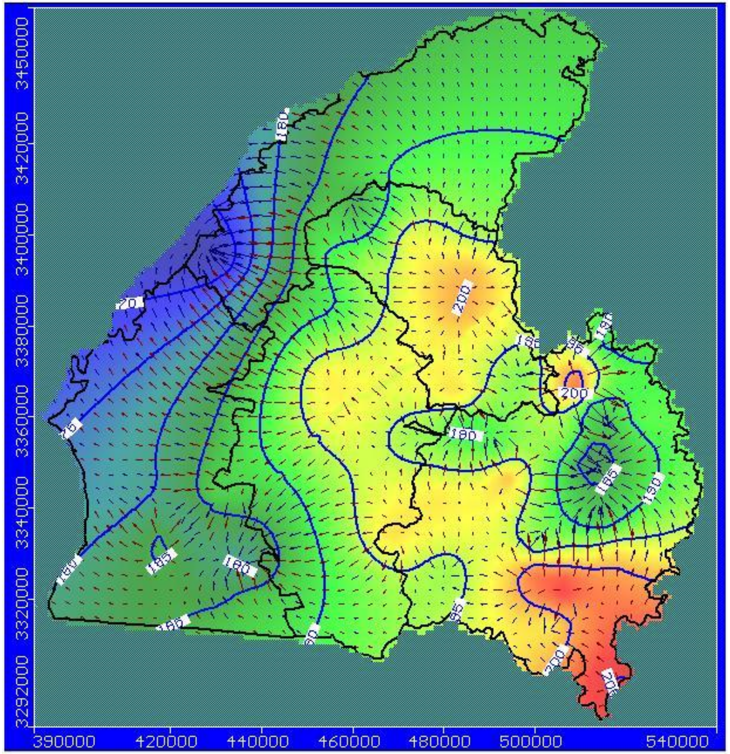


Shallow groundwater samples (<200 ft) fall under the category of permissible to doubtful and doubtful categories for irrigation use while majority of samples fall under the category of good to excellent.

4. Identify the most vulnerable zone(s) of advancing groundwater salinity

5. Investigate impact of excessive groundwater pumping in central Punjab on the movement of increased groundwater salinity, and

Groundwater modeling



The overall groundwater flow direction is towards the SW direction.

6. Suggest cost effective and eco-friendly management strategy for control of groundwater salinity

Types and Causes of salinity

Concentration of salts in water;
contains significant amounts (referred to as "concentrations") of dissolved salts,
the most common being the salt we all know so well—sodium chloride (NaCl).

- **natural/primary salinity caused as a result of dissolution of minerals (e.g. halite, anhydrite, carbonates, gypsum, fluoride-salts, and sulphate-salts) from bedrocks or accumulation of salts from rainfall built up over time, hence the residence time of these may be quite long ranging from thousands to million of years**
- **dryland/secondary salinity caused due to rising water levels which bring salt to the surface, In high rainfall areas the salts are percolated down while in arid and semi arid regions these remain on the surface**
- **tertiary/irrigated salinity caused as a result of repeated multiple irrigation of water where salts remain after evaporation and accumulate over time. These accumulated salts leech down to groundwater with rainfall.**

Types and Causes of salinity

Reviewing of the suggested causes

paleohydrological link with the Arabian sea;
evaporative enrichment of salts and
anthropogenic pollution

Proposed recommendations

Augmentation of groundwater

Water management options

Conjunctive use (or blending) in terms of water quality could be practiced to meet demand for non-drinking purpose. This could be achieved by blending poor quality water (brackish) groundwater with better quality water from canals to dilute the salinity. Such water could be used for horticulture, overland applications, gardening and cleaning purposes. This option can be tried in South west Punjab area where groundwater with EC < 4000 µS/cm is available. The saline water that will be pumped out could be replaced in due course of time by the freshwater through precipitation recharge or subsurface flow; this can be done by a careful planning and execution.

Regulation and limiting groundwater usage by enforcing groundwater legislation for future expansion of construction of wells farther inland, educating the farmers to reduce their present withdrawal to achieve groundwater balance and adopting water saving practices

Crop adaptation or change in cropping pattern to manage salinity in soils and water, through introducing crops with lower water requirements; introducing salt tolerant and semi salt tolerant crops may be one of the options
Aquifer Storage and Recovery (ASR) can first of all be approached as a storage technique where the aquifer is used as an underground reservoir.

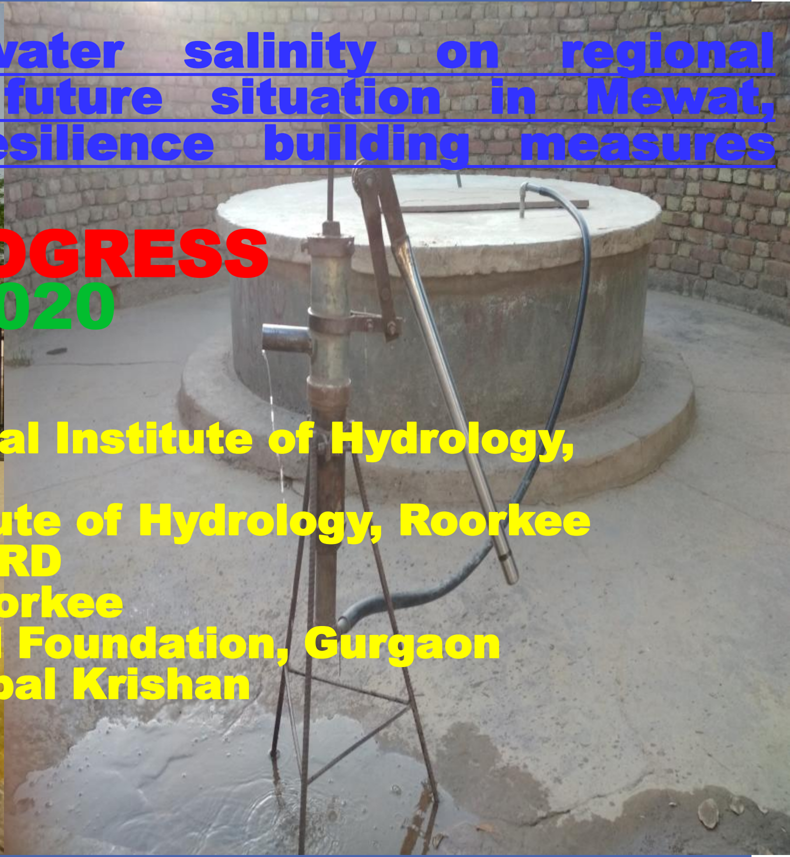
Changes in vegetation can also help improve the water and salt balances in soil, the vadose zone, and shallow groundwater. Since deep tree roots can efficiently pump underlying shallow groundwater, afforestation of grasslands reverses the vertical flux of groundwater from the soil to the saturated zone

Mass awareness programs

STUDY GROUP

	PRINCIPAL INVESTIGATOR	
1	**Dr. Gopal Krishan**	Scientist C and Project Leader, Groundwater Hydrology Division
	CO-INVESTIGATORS	
2	**Dr. S.K. Jain**	Ex-Director, NIH
3	**Dr. N.C. Ghosh**	Principal, Bengal Institute of Technology, Kolkata; Ex-Scientist G & Head, Groundwater Hydrology Division
4	**Er. C.P. Kumar**	Ex-Scientist G & Head, Groundwater Hydrology Division
5	**Dr. M.S. Rao**	Scientist F, Hydrological Investigation Division
6	**Dr. Anupma Sharma**	Scientist F, Groundwater Hydrology Division
7	**Dr. Surjeet Singh**	Scientist F, Groundwater Hydrology Division
8	**Dr. Sumant Kumar**	Scientist D, Groundwater Hydrology Division
9	**Smt. Suman Gurjar**	Scientist C, Groundwater Hydrology Division
	External Expert Support	
1	**Dr. Bhishm Kumar**	Consultant IAEA, Vienna, Austria, Ex. Scientist 'F' and Head, HID, NIH

	Supporting Staff	
10	*Smt. Anju Chaudhry*	SRA, Groundwater Hydrology Division
11	*Sh. Sanjay Mittal*	SRA, Groundwater Hydrology Division
12	*Sh. Mohar Singh*	PRA, Hydrological Investigation Division
13	*Sh. S.L. Srivastav*	SRA, Groundwater Hydrology Division
14	*Sh. Vipin Agarwal*	SRA, Hydrological Investigation Division
15	*Sh. Vishal Gupta*	RA, Hydrological Investigation Division
16	*Sh. Raju Juyal*	SRA, Computer Centre
17	*Sh. Sudarsan N*	JRF, Groundwater Hydrology Division



Assessment of impacts of groundwater salinity on regional groundwater resources, current and future situation in Mewat, Haryana – possible remedy and resilience building measures

PDS ANNUAL PROGRESS

November 2020

IA : **National Institute of Hydrology, Roorkee**

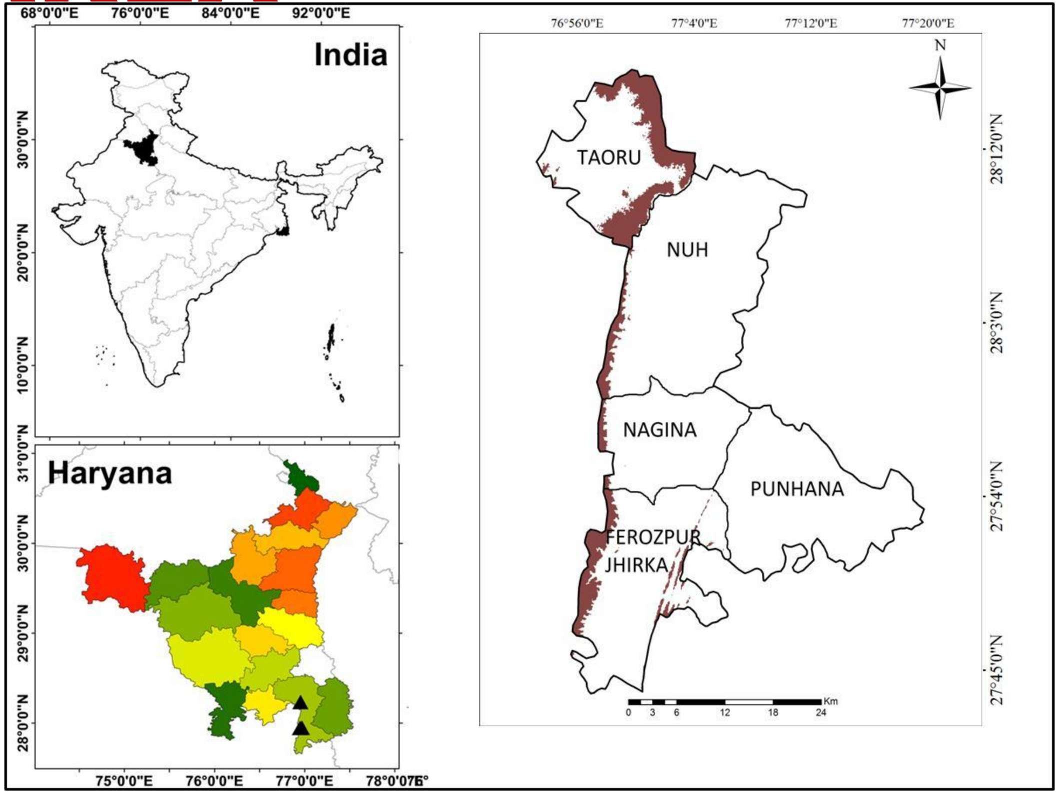
Lead Organisation : **National Institute of Hydrology, Roorkee**

Partner Organisations: **Haryana Irrigation & WRD**
IIT, Roorkee
Sehgal Foundation, Gurgaon

PI : **Dr. Gopal Krishan**

Budget : **65 lakhs**
2018-2021

STUDY AREA



General & Hydrological Features

27° 39' & 28° 20' N, 76° 51' & 77° 20' E

Population= 10,89,263(2011, census)

Area(Sq. Km):1,859.61

Average rainfall: 594 mm

Forest: 30, cultivable area: 1361

GROUND WATER RESOURCE AND DEVELOPMENT POTENTIAL

Assessment Unit/Block	Net Ground Water Availability Ham	Existing Gross Ground Water Draft for irrigation Ham	Existing Gross Ground Water Draft for all uses Ham	Allocation for domestic and industrial requirement supply upto next 25 years Ham	Net Ground Water Availability for future irrigation development Ham	Stage of ground water Develop-ment in %	Category of Block
Ferozpur Jhirka	4727	2741	3011	450	1536	64	Over Exploited
Nagina	4185	1813	2025	354	2018	48	safe
Nuh	4526	1701	2011	507	2318	44	Safe
Punhana	5420	3724	3910	323	1373	72	Critical
Tauru	2765	3301	3496	195	-731	126	Over Exploited
Total	21623	13280	14453	1830	6513	67	

CGWB, 2012

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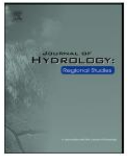
journal homepage: www.elsevier.com/locate/ejrh



Identifying the seasonal variability in source of groundwater salinization using deuterium excess- a case study from Mewat, Haryana, India

G. Krishan[a,*], G. Prasad[a], Anjali[a], C.P. Kumar[a], N. Patidar[a], B.K. Yadav[b], M.L. Kansal[b], S. Singh[a], L.M. Sharma[c], A. Bradley[d], S.K. Verma[a]

[a] National Institute of Hydrology, Roorkee, Uttarakhand, India
[b] Indian Institute of Technology Roorkee, Uttarakhand, India
[c] Sehgal Foundation, Gurgaon, Haryana, India
[d] The University of Iowa, Iowa City, Iowa, 52242, USA

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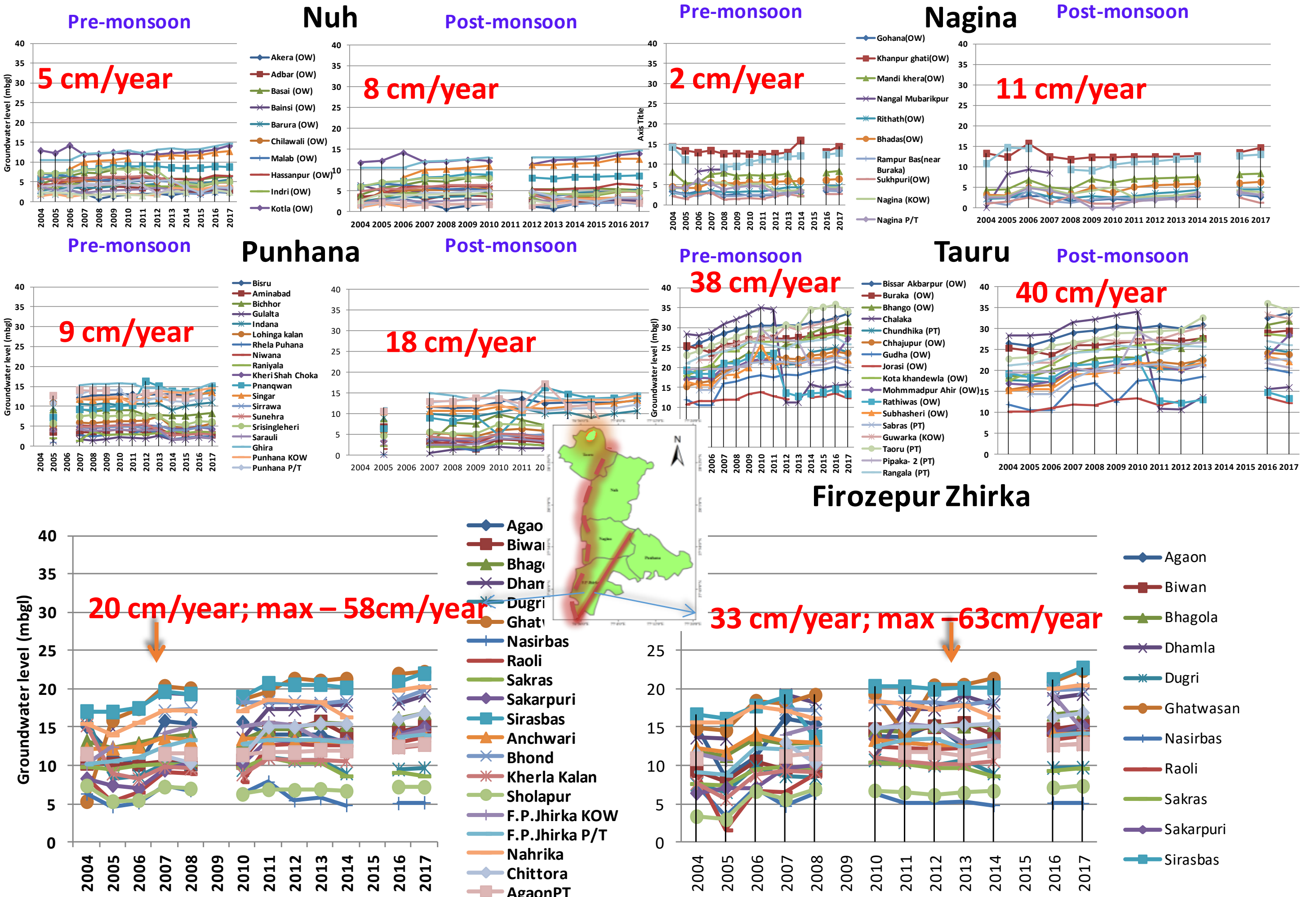
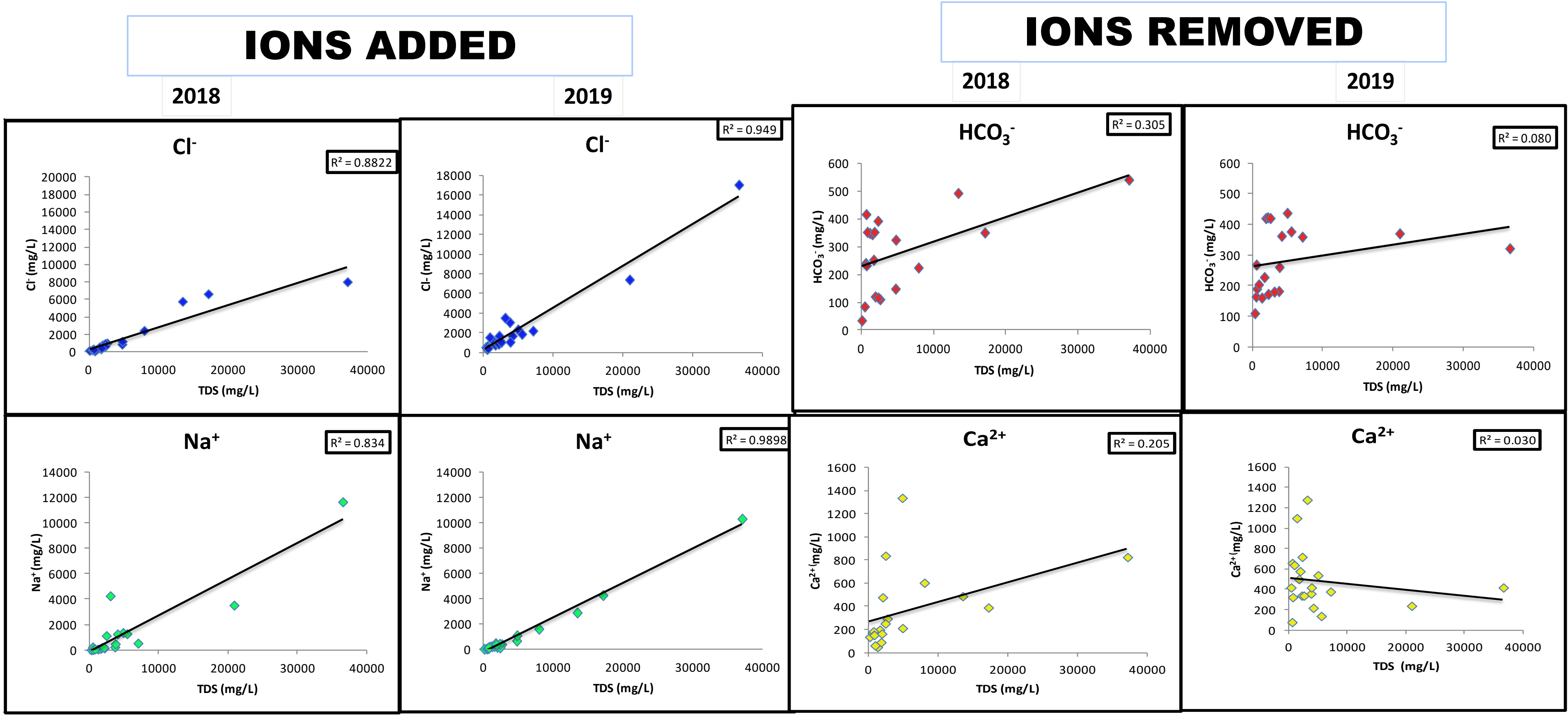
Understanding stable isotope systematics of salinity affected groundwater in Mewat, Haryana, India

Gopal Krishan[1,*], N C Ghosh[1], C P Kumar[1], Lalit Mohan Sharma[2], Brijesh Yadav[3], M L Kansal[3], Surjeet Singh[1], S K Verma[1] and Gokul Prasad[1]

[1] *National Institute of Hydrology, Roorkee, Uttarakhand 247 667, India.*
[2] *Sehgal Foundation, Gurugram, Haryana 122 003, India.*
[3] *Indian Institute of Technology, Roorkee, Uttarakhand 247 667, India.*
**Corresponding author. e-mail: drgopal.krishan@gmail.com*

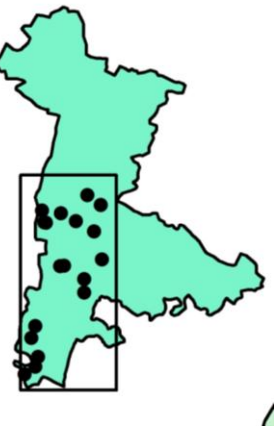
Groundwater level variations 2004-17

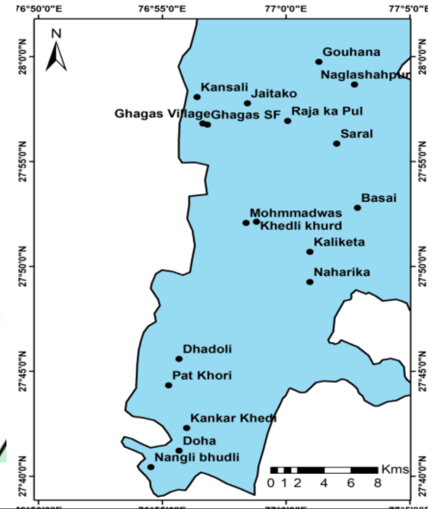


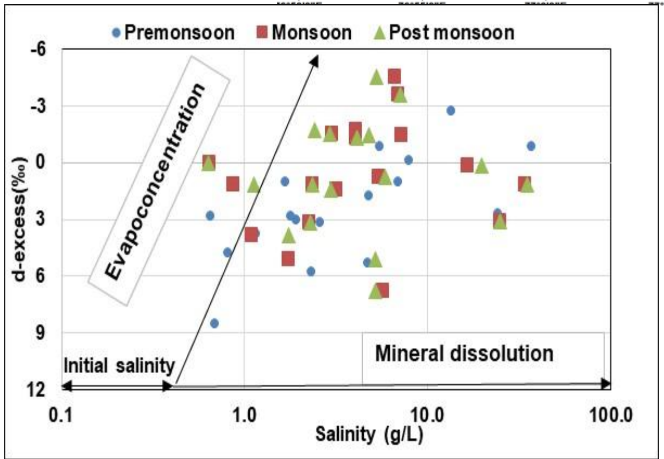

IONS ADDED
2018
2019
IONS REMOVED
2018
2019
Cl-
R² = 0.8822
Cl- (mg/L)
TDS (mg/L)
Cl-
R² = 0.949
Cl- (mg/L)
TDS (mg/L)
HCO3-
R² = 0.305
HCO3- (mg/L)
TDS (mg/L)
HCO3-
R² = 0.080
HCO3- (mg/L)
TDS (mg/L)
Na+
R² = 0.834
Na+ (mg/L)
TDS (mg/L)
Na+
R² = 0.9898
Na+ (mg/L)
TDS (mg/L)
Ca2+
R² = 0.205
Ca2+ (mg/L)
TDS (mg/L)
Ca2+
R² = 0.030
Ca2+ (mg/L)
TDS (mg/L)

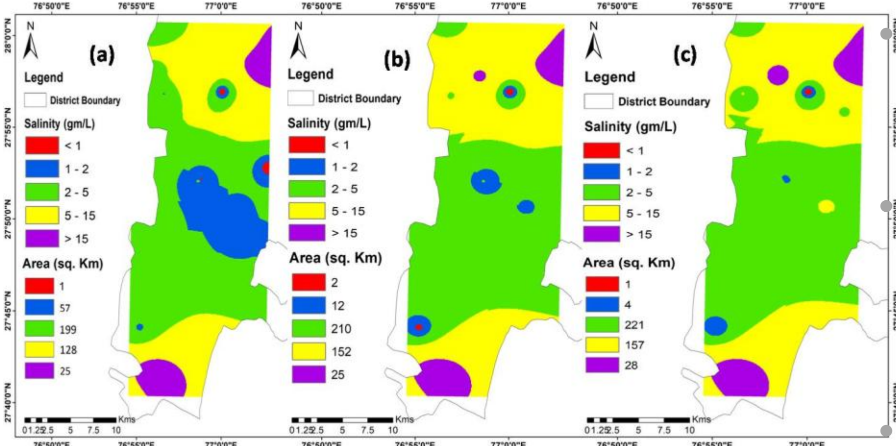
Variations in Salinity

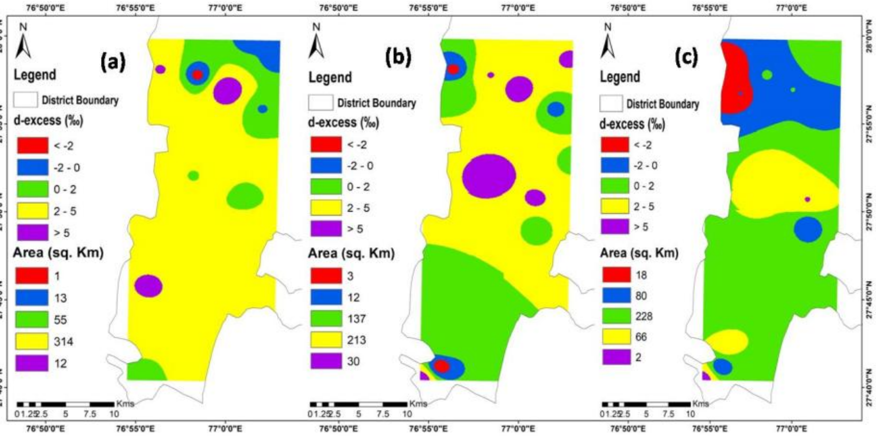
a-pre monsoon; b-monsoon; c- post monsoon





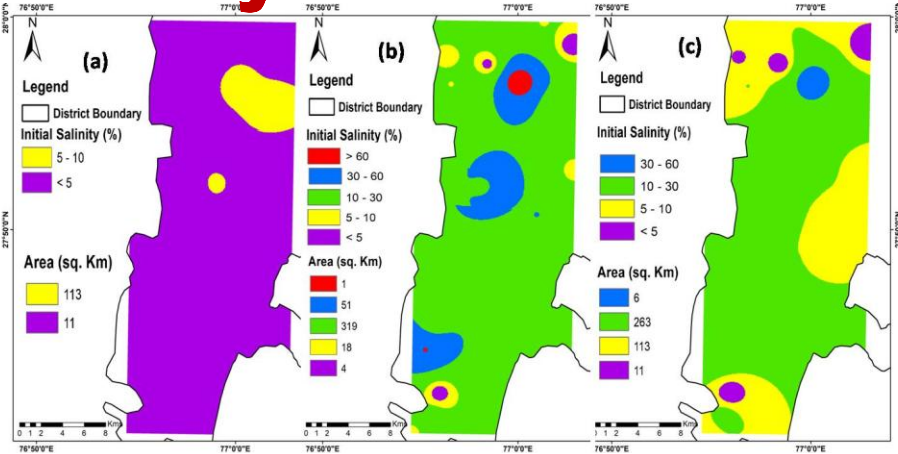


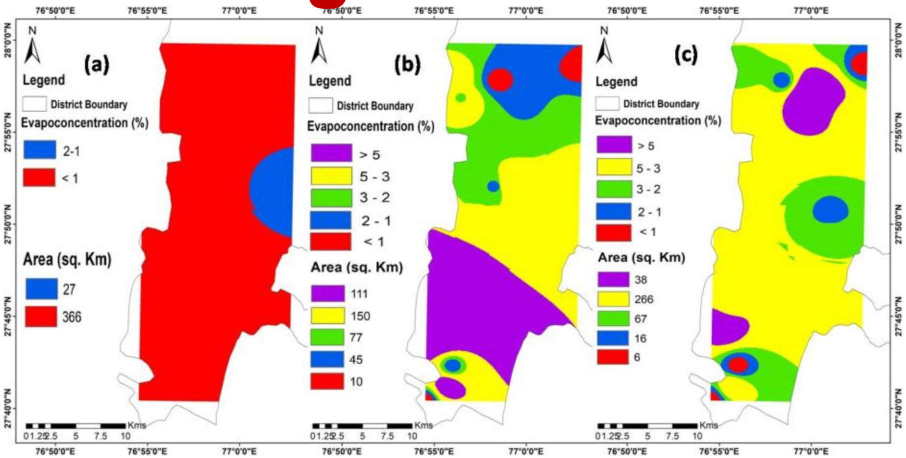


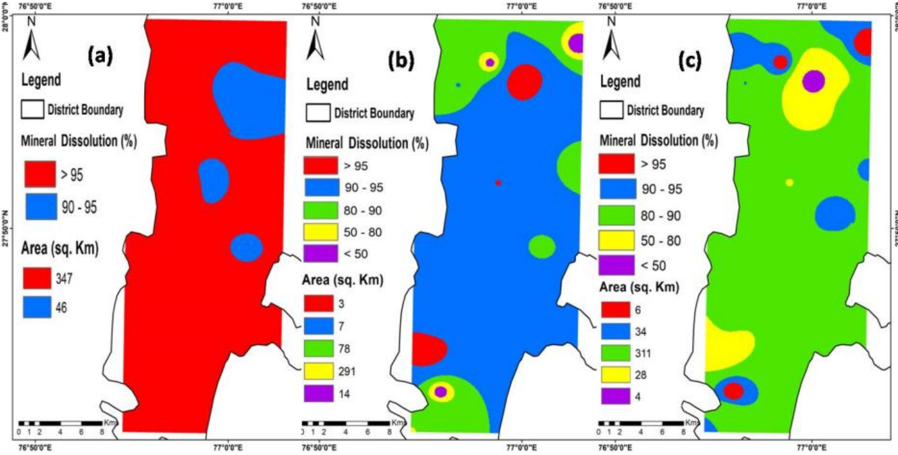


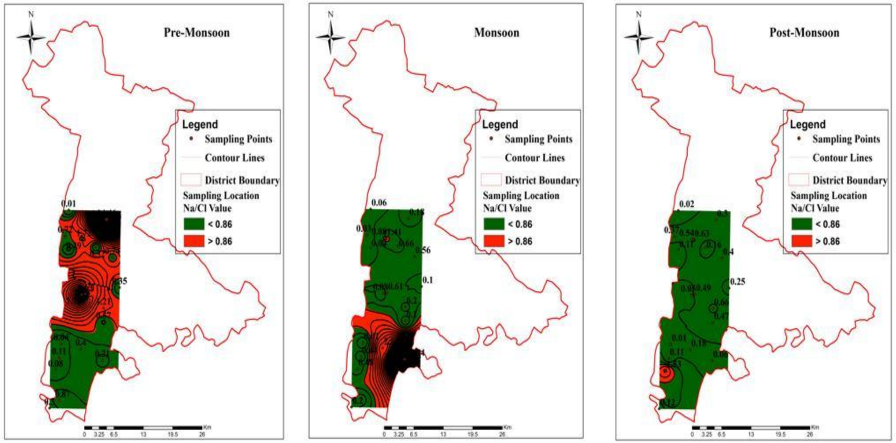
- Increasing chlorides with time
- Na/Cl ratios (<0.86 molar ratios of salt intrusion)
- D-excess: an important parameter to identify salinity mechanism

Salinity identification/understanding

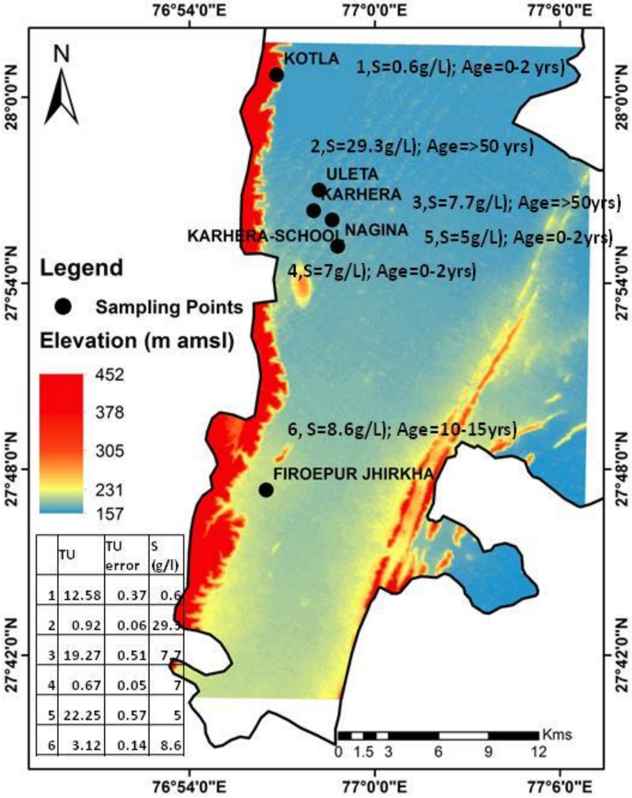


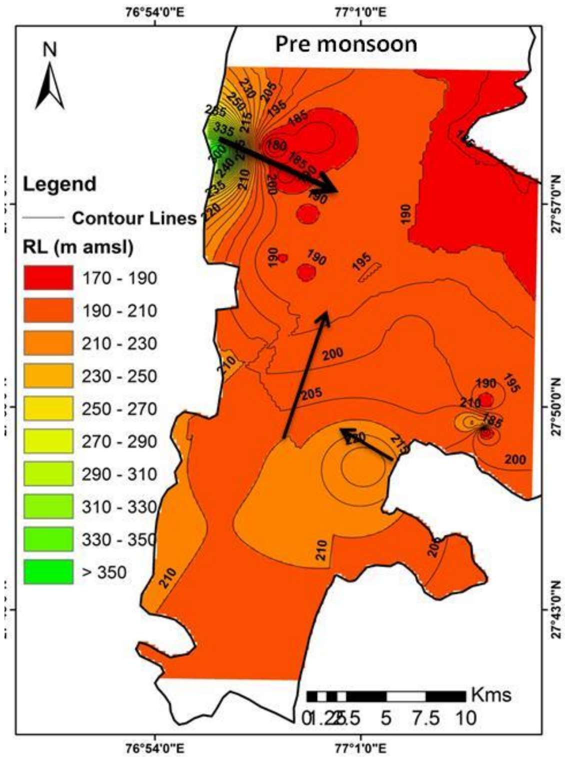


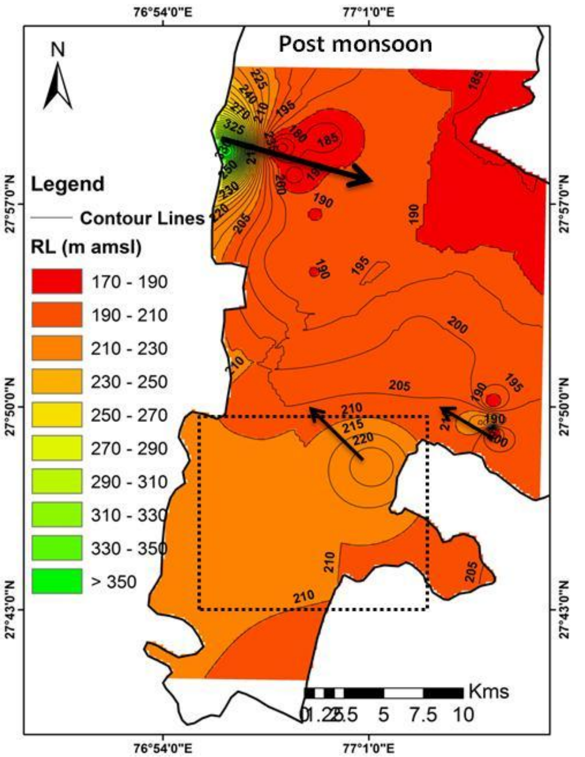




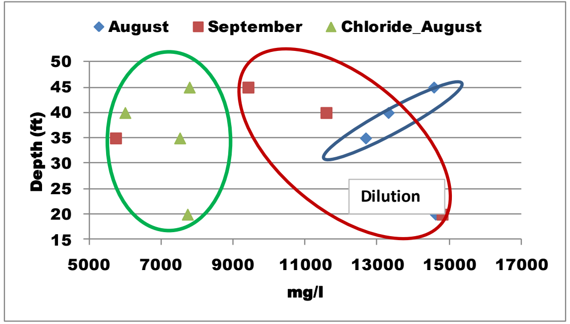
Salinity identification/understanding

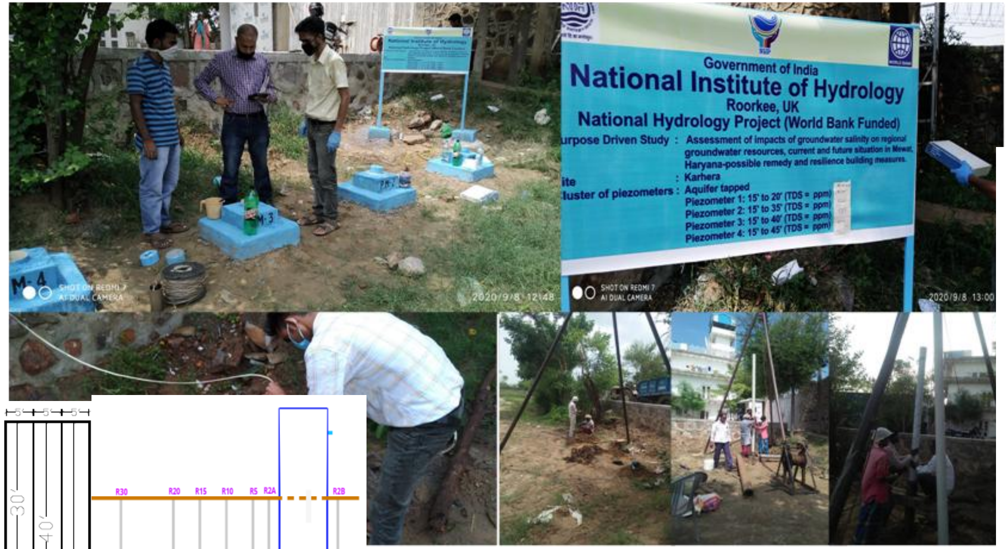


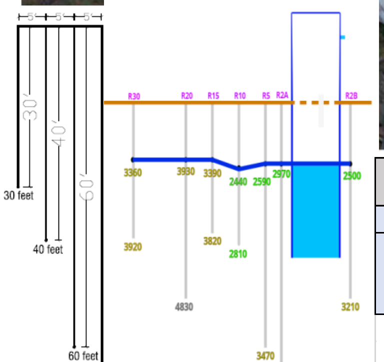




Development of piezometers

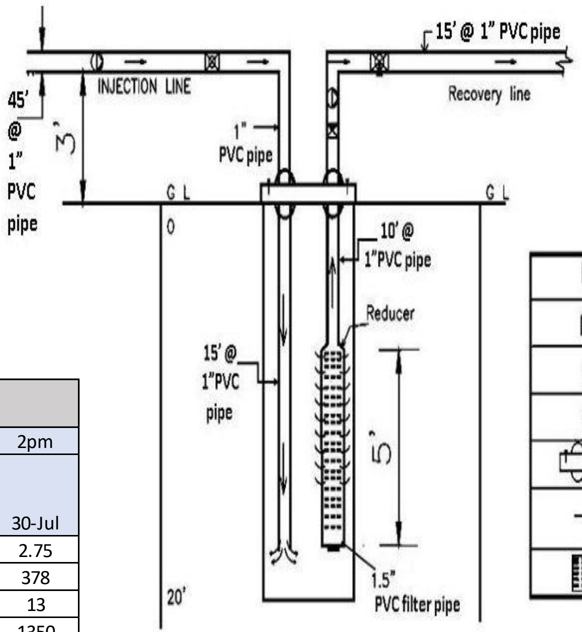


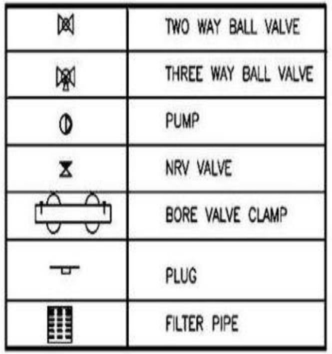




Total Dissolved Solids [1]

< 500 ppm
500-3000 ppm
3000-4000 ppm
> 4000 ppm





Location- Karhera School							
		Time	1.25pm	11.AM	12pm	10am	2pm
Sr. No	distance from centre	Indicators	Feb	March	April	31-May	30-Jul
	2.1R	Water Level	9.1	11	3.45	3.59	2.75
		Salinity in WL	2970	2950	4670	3270	378
		Bottom Level	44.1	44	13.29	12.1	13
		Salinity in BL	4420	6330	14900	6510	1350
		Water Level	8.5	12.02	3.73	3.68	3.15

Ground Water Recharge, Reduction in Soil Salinity solutions and way forward for Indian Sunderbans

NATIONAL INSTITUTE OF HYDROLOGY
राष्ट्रीय जलविज्ञान संस्थान
आपो हि ष्ठा मयोभुवः

BGS 1835
British Geological Survey
Expert | Impartial | Innovative

Ground Water Concerns in Indian Sundarbans

- **Increased pressure on sweet water sources lead to ground water exploitation by farmers (Ground water depletion rate is 3m and 2.5m per annum in 1^{st} and 2^{nd} aquifer, respectively) (CGWB Report, 2019)**
- **Increased salinity (2.2-4.1 dS/m) in shallow aquifers with increased abstraction**
- **Alteration of the nature of surface water from sweet to brackish (>15-20ppm) during summer and winter seasons**
- **Toxic effect of salinity on farm lands impacting towards crop loss (34-40% crop loss occur during summer seasons)**
- **Presence of sodic-soil layer at 6-8ft depth (CSSRI Report, 2016) in majority of the islands**
- **Periodic inundation by saline water in every 5 years leads to river embankment failure in Indian Sundarbans (IPCC Dissemination Report, 2019)**
- **Piezometric heads failing from as early as Mid-February to Mid-June every year**
- **Trading of irrigation water taking place from ground water and surface water sources (during February to June every year)**

Change in nature of surface water

High salinity and crop loss

Periodic Inundation

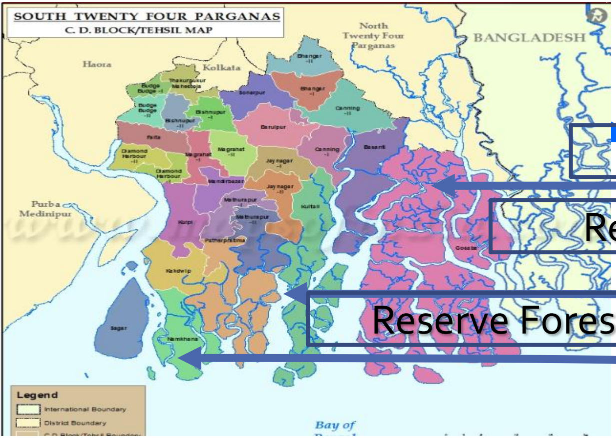
Dry and Saline soil

Geographical area

- **Sundarbans – the mangrove delta of Ganga - Bramhaputra**
- **Spread across India and Bangladesh – it constitutes 9 % of total area of West Bengal**
- **Two districts- North 24 Parganas (9 blocks) and South 24 Parganas (13 blocks) – 54 habituated islands**
- **Mangrove coverage 4463.89 sq. Km. in Indian Sundarbans**

places); high p

ins

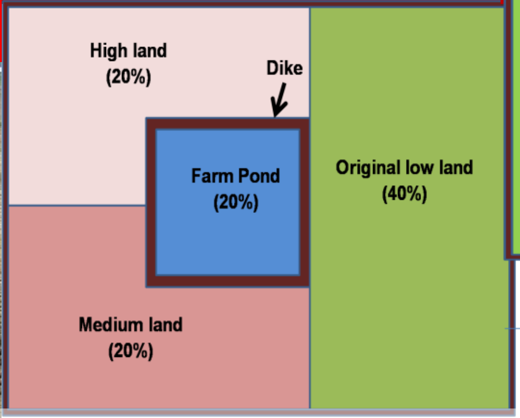


Haldar & Debnath 2014

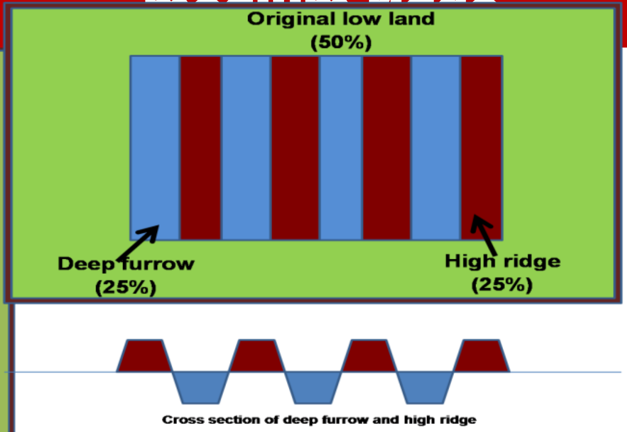
ACWADAM

Restoring coastal delta by strengthening drainage channels

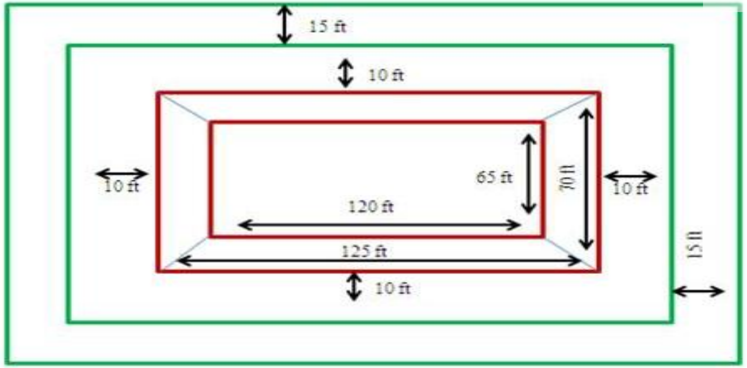
Farm pond technique



Shallow furrow and



Brackishwater aquaculture



Agroforestry system in coastal salt affected soils

Land should be raised more than 50 cm to grow the tree species.

Land shaping provide less salinity build up and higher soil moisture during dry months.

Agro-forestry trees like, Eucalyptus, Acacia auriculiformis, Casuarina, Herietiera, Brugeria,

Surface water management under saline conditions

Why Five-square model relevant for the area?

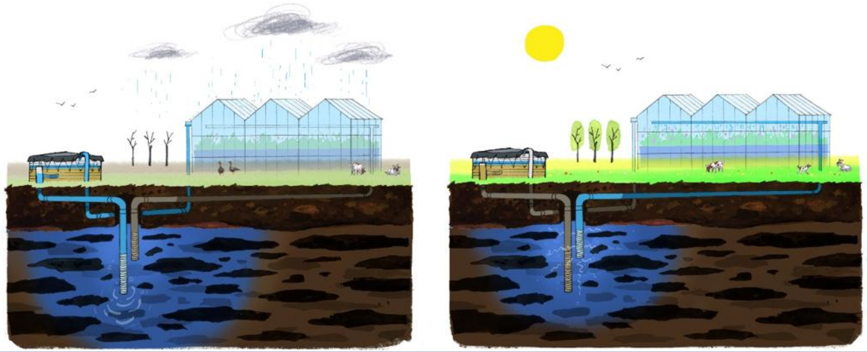
- Five-square model is known for salinity check and reducing water stagnation in Indian Sundarbans' context
- Model is included as one of the scheduled activities under MGNREGA
- Known for creating impact on cropping intensity and non-cyclic salinity reduction as well
- Positive impact on reducing forced migration and diversifying livelihood vocations
- Stable source for water supply for ASR during rainy season

Economics of Surface Water Management

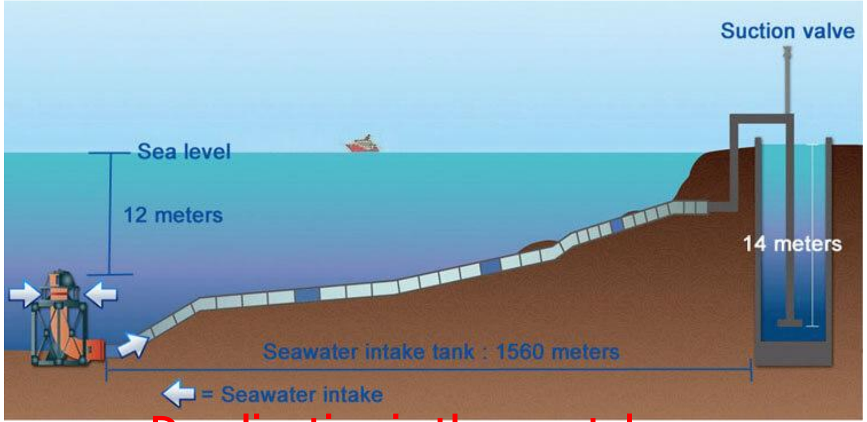
- **Land use management cost for 0.34acre land is INR 90,000/- at current price**
- **Benefit out of the farming system is expect INR 65000-70000/- per annum**
- **Break Even in one and half years**
- **Annual maintenance of the system is as low as INR 5000/-**
- **Benefit cost Ratio for the system is 2.88 per Ha**
- **Increase in cropping intensity for the system is expected 30-35% per Ha**
- **Increase in total production is expected 35-40% per Ha**
- **Expected incremental net income per Ha is INR 2-2.5 Lacs**

Ground Water Stress and Probable Solutions

- **Increasing availability of surface water**
- **Aquifer storage and recovery to increase sweet water availability in a saline aquifer**
- **Salinity management through surface water management**
- **Crop water management**
- **Desalination of river water and supply through pipes (it is not possible in Indian Sundarbans due to high silt content in the water)**
- **Protection of river embankment to reduce cyclone/flood impact**



ASR in the coastal area; Source: BGS



Desalination in the coastal area; Source: BGS

Economics of ASR

- **Sweet water production cost/ cost calculation for ASR**
  - **Cost of water harvesting structure+ solar pump (0.1-0.25HP)+ injection and recovery pipes+ cost of valves, taps etc = (annual operation cost+ maintenance cost) / annual total freshwater production**
  - **Benefit Cost Ratio per Ha = 160000 / 60000 = 2.66**

Proposed benefits

Maximization of sweet water availability for critical irrigation in summer and winter

Increased access to fresh drinking water by 30% per HH

Storage of ground water in ASR against adverse climatic conditions common in Indian Sundarbans

Expected increase in cropping intensity by 35-43% per Ha

Expected increase in overall farm production by 23-26% per HH

Improved net income of the farmers with cost 2.66 benefit-cost ratio per Ha

Thanks…

Funding from PSFC;
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BGS
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Prasari