Impact of Climate Change on Water Resources - the case of Coastal Basin South-Eastern Tanzania

10th Alexander von Humboldt Conference 2015 (AvH10)

Water-Food-Energy River and Society in the Tropics

Gullele Botanic Garden, Addis Ababa, Ethiopia 18th. November 2015

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Background

The rapid pace of urban development,

prolonged droughts and deforestation

has led to increased the demand for freshwater resources in coastal Tanzania

	Current (2012)	Projected (2020)
Population	≈ 4,000,000	> 5,000,000
Water demand (m^3/day)	300,000	600,000
Actual water supply (m^3/day)	200,000	
Water deficit (m^3/day)	100,000	

Searching for groundwater sources as a supplement to surface water

The regional Neogene aquifer was discovered in the alluvial plain of coastal area in Dar es Salaam

- 6-deep wells to > 600m depth were drilled
- One artesian well

Research questions?

- What is the recharge provenance of the coastal groundwater?
- What is the quality of groundwater in the coastal aquifer systems?
- Is the saline groundwater in the aquifer resulting from seawater intrusion? OR
- Is there water-mass mixing with other pollutants from recharge zones?

Main objective

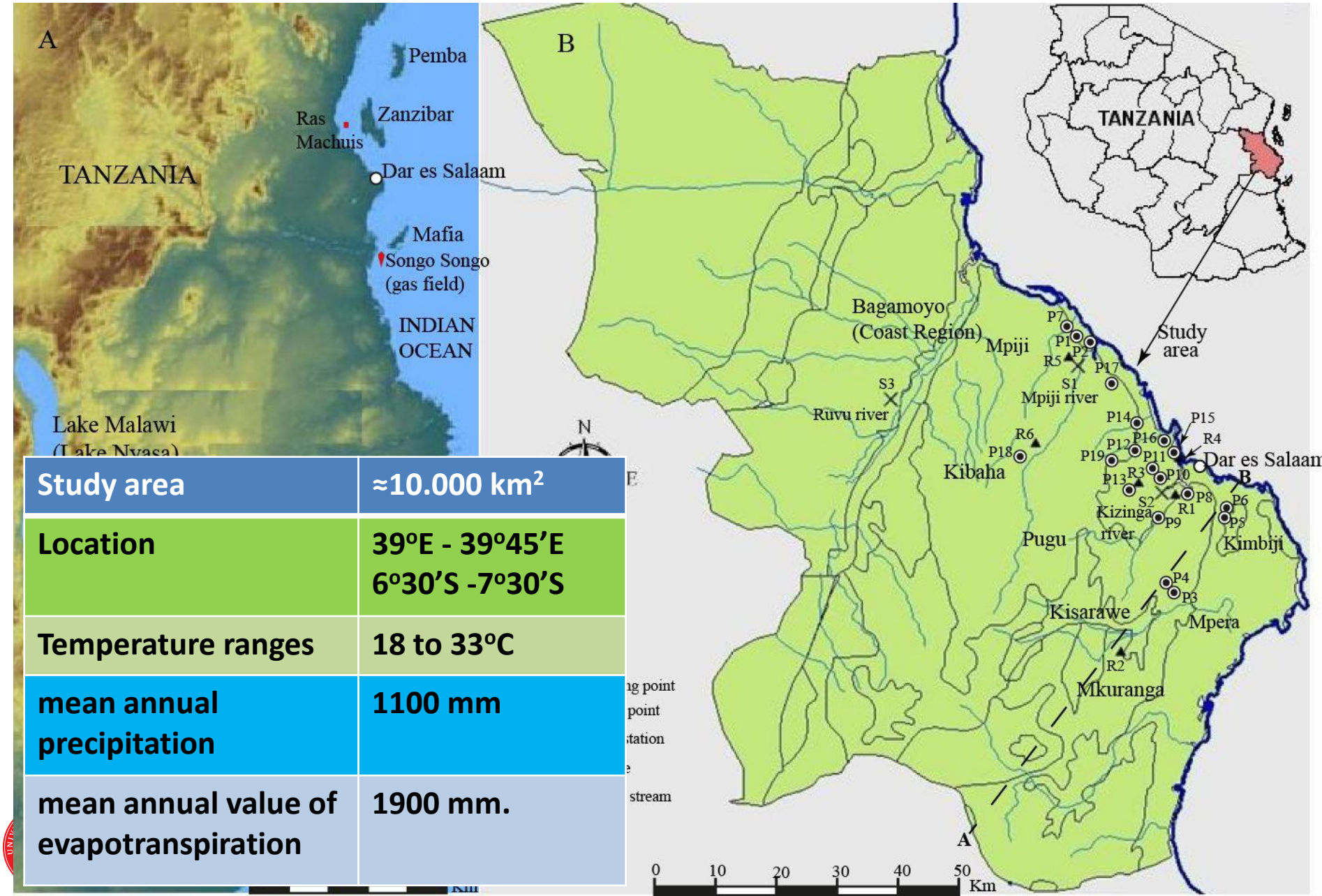
To identify the major factors affecting groundwater quality and the origin of groundwater salinity in Dar es Salaam

Specific objectives

- To determining the processes and factors that control the groundwater composition by means of statistical analyzes of water chemistry

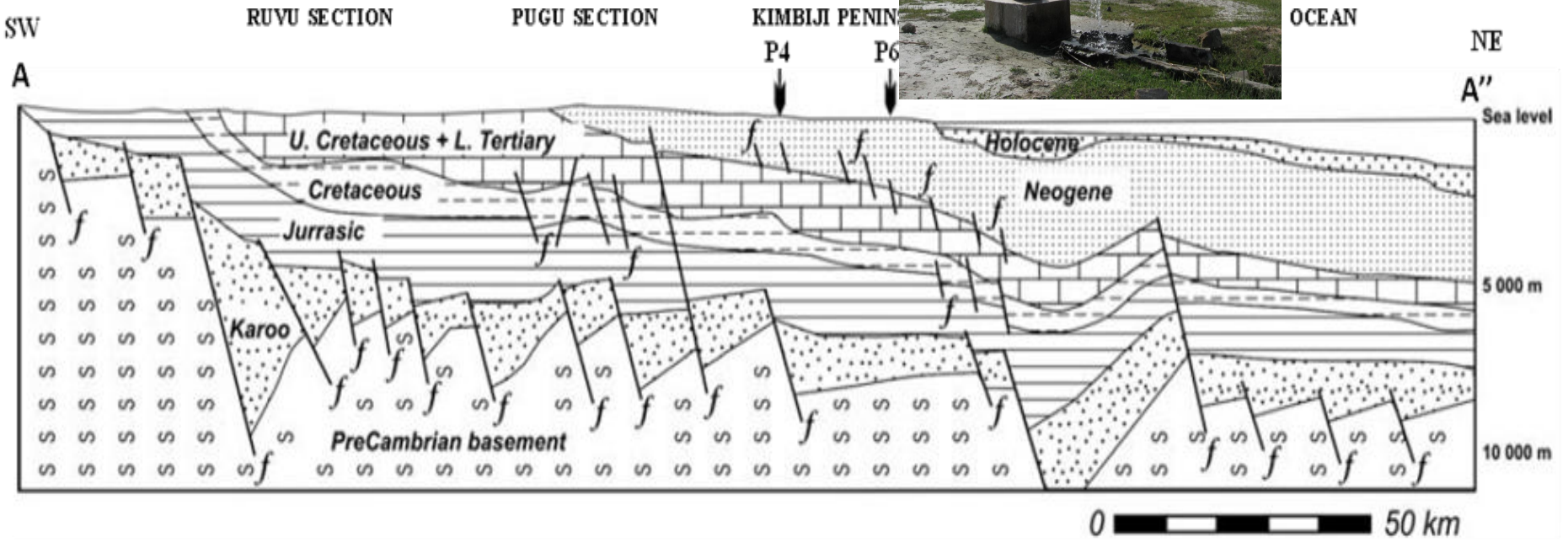
- Investigating the origin and type of recharge using stable isotopes of ^{18}O and ^{2}H.

Study area and hydrogeological setting



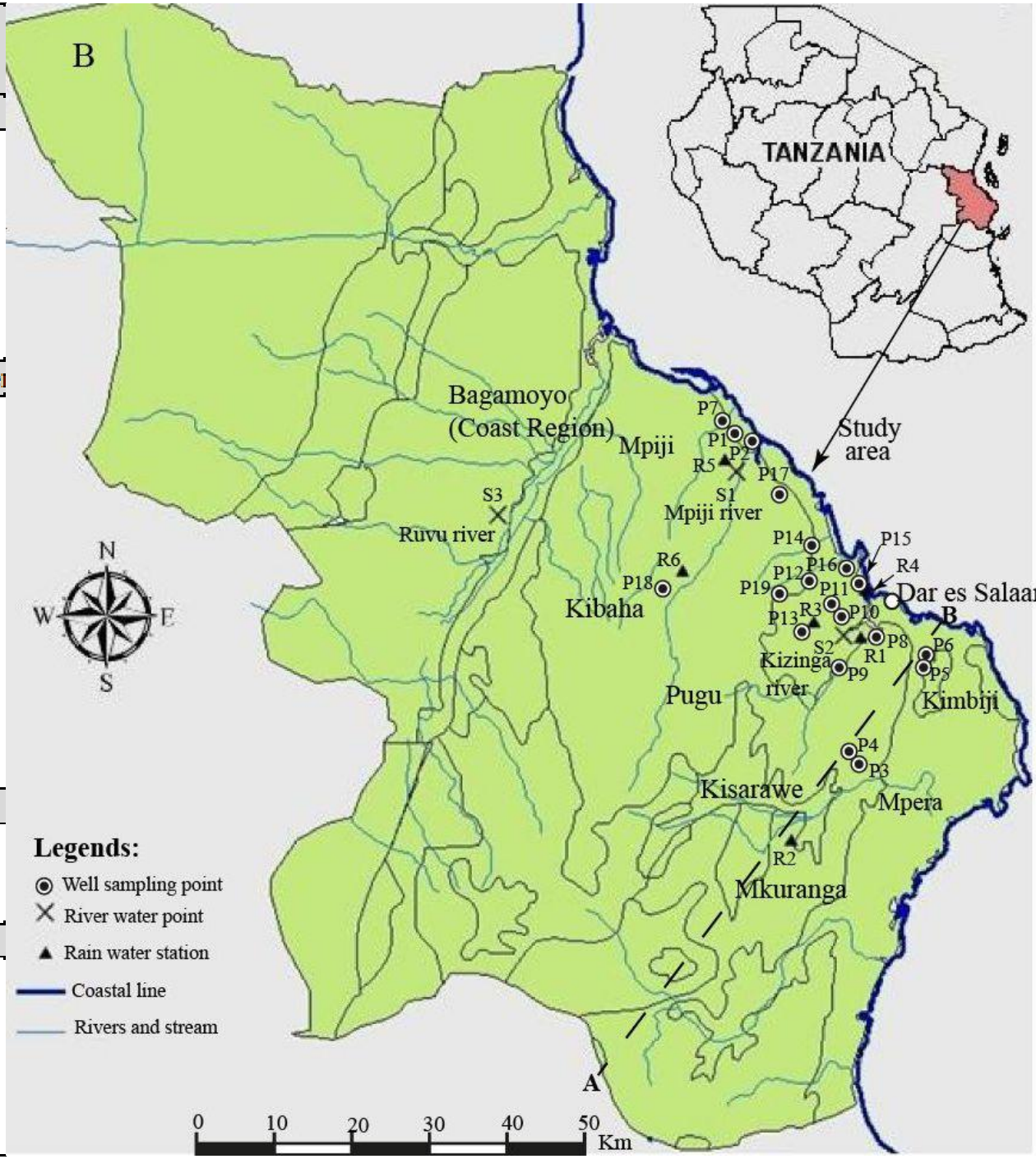
Study area	≈10.000 km²
Location	39°E - 39°45'E 6°30'S -7°30'S
Temperature ranges	18 to 33°C
mean annual precipitation	1100 mm
mean annual value of evapotranspiration	1900 mm.

Hydrogeology of the aquifer



- Average saturated thickness of the aquifer ≈ 1000 m
- Flow direction: W-E driven by artesian pressure from western hinterland

Sample Code	Site name	Total depth (m)
♯Lower confined aquifer		
P-1	Mpiji	200
P-2	Mpiji	610
P-3	Mpera	200
P-4	Mpera	600
P-5	Kimbiji	200
P-6	Kimbiji	612
P-13	Airport	100
§Upper unconfined aquifer		
P-7	Mpiji	80
P-8	Kijichi	50
P-9	Mbagala	70
P-10	Tandika	53
P-11	Tazara	65
P-12	Tabata	60
P-14	Kigogo	60
P-15	Ocean Road	11
P-16	M´nyamala	50
P-17	Tegeta	65
P-18	Kibaha	95
P-19	Ubungo	70
♯River water		
S-1	Mpiji	
S-2	Kizinga	
S-3	Ruvu	
Rain water		
R-1	Kijichi	
R-2	Mkuranga	
R-3	Airport	
R-4	Ocean Road	
R-5	Bagamoyo	
R-6	Kibaha	

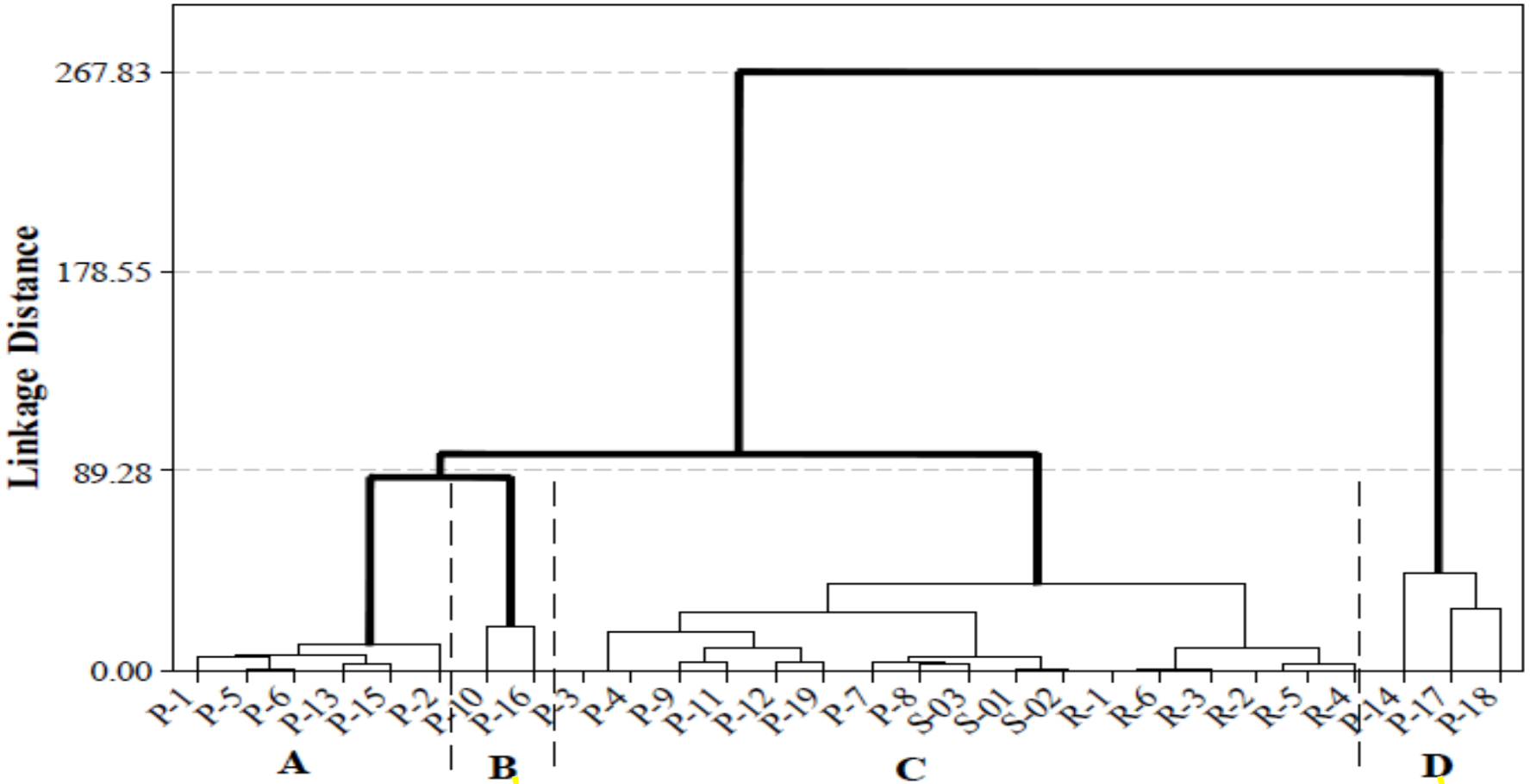


Result and discusion

Paper I: Delineation of groundwater provenance in a coastal aquifer using statistical and isotopic methods, South-East Tanzania

Published by Environ Earth Sci (2012) 66:889–902
DOI: 10.1007/s12665-011-1299-y

HCA classified groundwater into four groups (A, B, C, D), based on salinity, bicarbonate contents and nitrate concentrations



High HCO_3^- & moderate salinity

NO_3 contaminated water

Low & intermediate- salinity

High salinity

Factor analysis show that, 3 factors controlling geochemical processes of groundwater in the study area, explained 80.6% of the total data variance

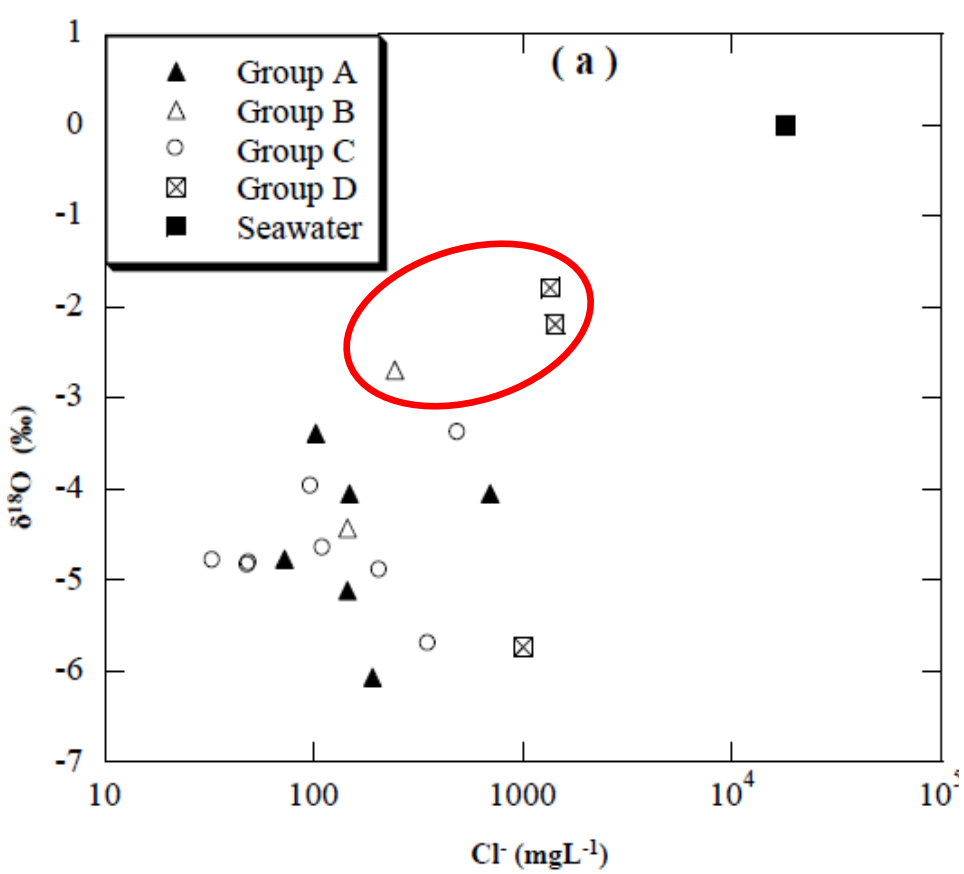
Variable	Factor I	Factor II	Factor III
pH	0.00	**-0.87**	-0.17
DO	-0.19	**0.77**	-0.24
EC	**0.96**	-0.25	0.10
Na^+	**0.90**	-0.35	0.03
K^+	0.04	-0.10	**0.86**
Mg^{2+}	**0.88**	-0.03	0.12
Ca^{2+}	**0.88**	-0.04	0.16
Mn^{2+}	0.15	-0.14	**0.69**
Cl^-	**0.97**	-0.17	0.01
NO_3^-	0.07	0.21	**0.90**
SO_4^{2-}	**0.94**	-0.00	-0.01
HCO_3^-	0.36	**-0.89**	0.05
Br^-	**0.71**	-0.25	0.22
Eigenvalues	5.779	2.489	2.214
% of Variances	44.5	19.1	17.0
Cumulative %	44.50	63.60	80.60

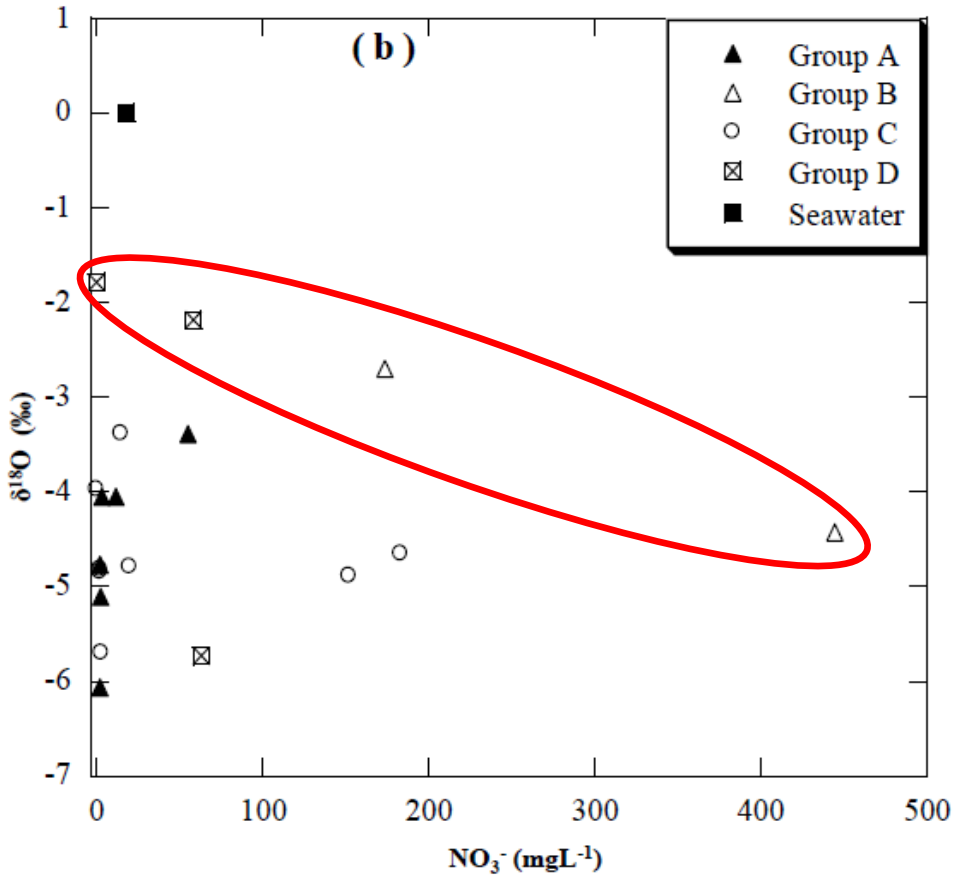
seawater intrusion –as group C and D in CA

groundwater contaminated by sewage, group C

residence time g/w, recharge dilution and water– rock interaction, group A

Isotopic variation of $\delta^{18}O$ show that shallow wells are contaminated with both seawater intrusion and discharge of sewage





Groundwater mixing and processes affecting water quality in the coastal aquifer system*

	pH	DO	EC	Na^+	K^+	Mg^{2+}	Ca^{2+}	Mn^{2+}	Cl^-	NO_3^-	SO_4^{2-}	HCO_3^-
pH	1.00											
DO	-0.44	1.00										
EC	0.22	-0.38	1.00									
Na^+	0.26	-0.47	**0.96**	1.00								
K^+	-0.02	-0.23	0.17	0.10	1.00							
Mg^{2+}	0.00	-0.25	**0.87**	**0.85**	0.12	1.00						
Ca^{2+}	0.09	-0.16	**0.87**	**0.71**	0.20	0.65	1.00					
Mn^{2+}	0.04	-0.18	0.25	0.18	0.39	0.20	0.29	1.00				
Cl^-	0.15	-0.31	**0.98**	**0.96**	0.06	**0.88**	**0.82**	0.22	1.00			
NO_3^-	-0.30	-0.11	0.10	0.03	**0.73**	0.21	0.17	0.46	0.02	1.00		
SO_4^{2-}	0.05	-0.20	**0.89**	**0.79**	0.10	**0.78**	**0.92**	0.02	**0.86**	0.09	1.00	
HCO_3^-	**0.74**	**-0.71**	0.57	0.62	0.18	0.35	0.37	0.20	0.49	-0.12	0.34	1.00

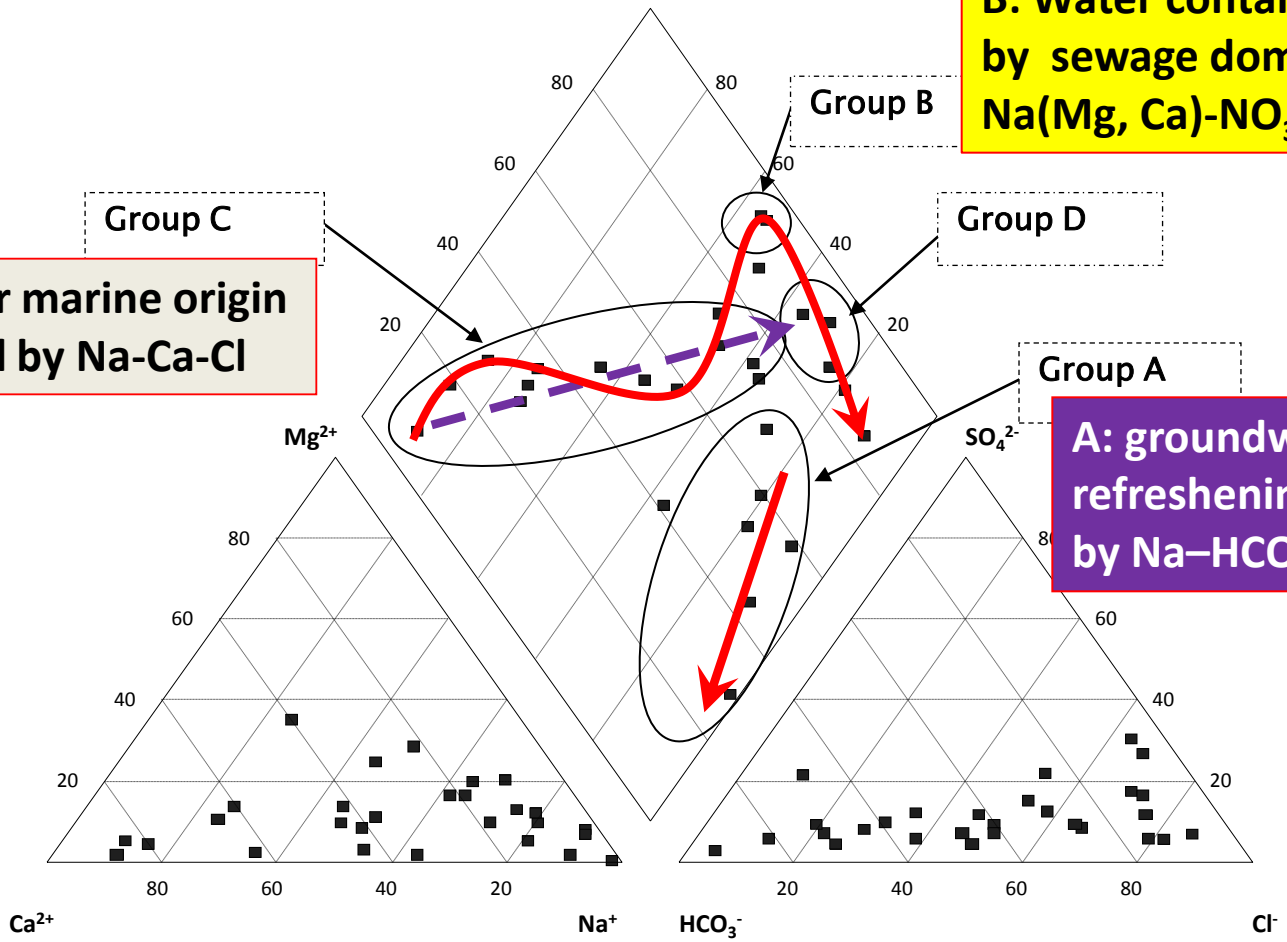
*Pearson correlation coefficients

The hydrogeochemical composition and processes affecting the groundwater quality

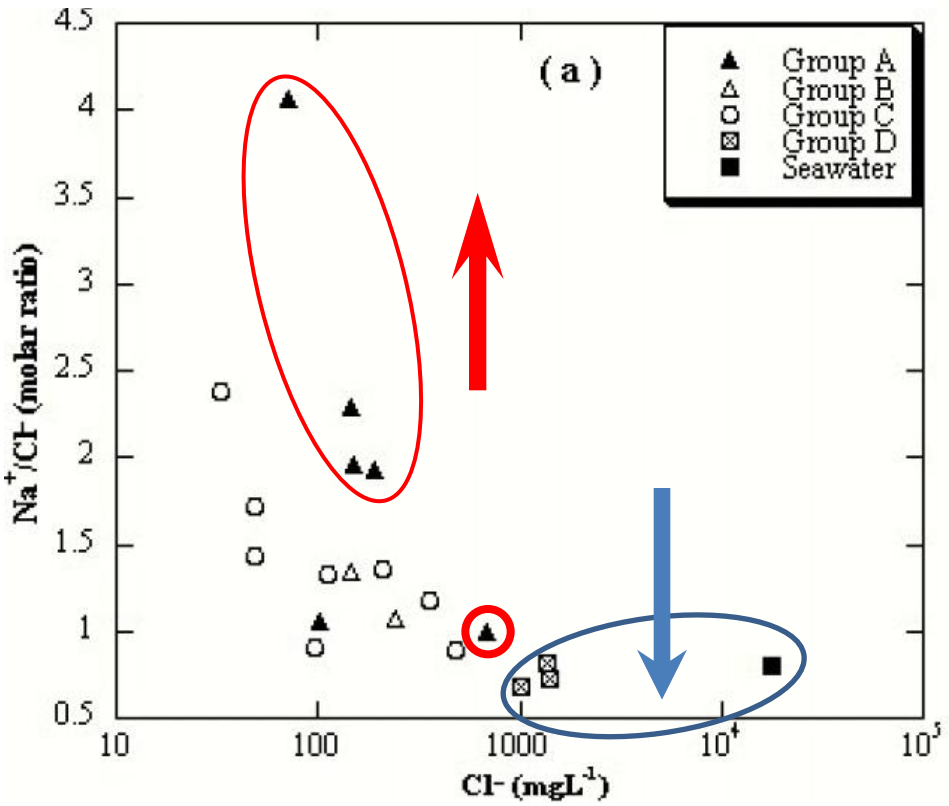
B: Water contaminated by sewage dominated by Na(Mg, Ca)-NO_3 type

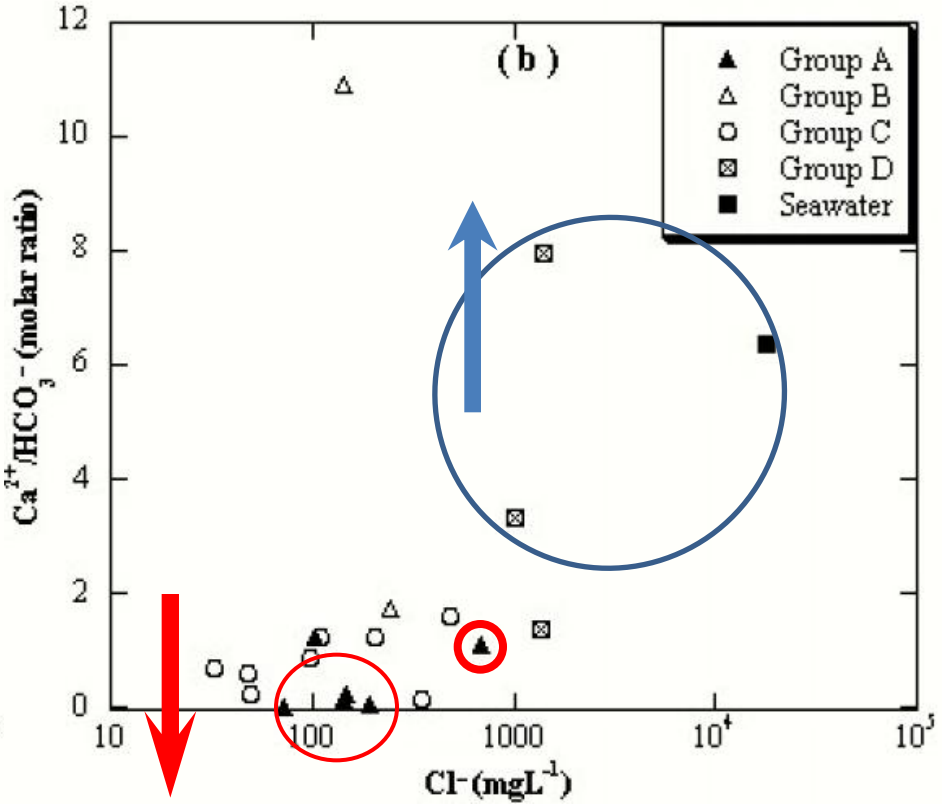
C &D: fall under marine origin site, dominated by Na-Ca-Cl

A: groundwater refreshening dominated by Na–HCO_3 water type



Our results show that the cation exchange reaction is the most important geochemical process occurring in the coastal aquifer





Summary

- CA results show that the groundwater in the study area may be classified into four groups (A, B, C and D).
- FA revealed that groundwater composition is mainly affected by three processes; seawater intrusion, dilution of groundwater by recharge, and sewage infiltration.
- Hydrogeochemical data of shallow well samples are dominated by Na-Ca-Cl type with Cl^- as the dominant anion due to the effect of seawater intrusion.
- The deep groundwaters are slightly to moderately mineralized and are of Na-HCO_3 type induced mainly by ion exchange reactions.
- Stable isotopes signatures supplement this assessment by suggesting groundwater origin and which pressures might be influencing the groundwater quality.

- Most of the shallow groundwater is not suitable for drinking water because of its high salinity which is mainly caused by saltwater intrusion and/ or man-made pollutants.

- The observation of NO_3^- in some of the deep groundwaters is alarming that the aquifer system is susceptible to cross-flow between aquifer units and surface pollution unless stringent protective measures are taken during future well construction and installations.

- The knowledge generated by this study constitutes a conceptual framework for investigating groundwater characteristics, and may be useful for modellers in their attempts to simulate the hydrogeological processes in the coastal aquifer over very long time spans.

Acknowledgments

Thanks the staff of the;-

- Dar es Salaam water supply authority (DAWASA) and the Ardhi University-Dar es Salaam for their support during the sampling campaign.

- Technicians in the Department of Geosciences laboratory, University of Oslo for helpful water samples analysis.

- The Quator Scheme Programme and Department of Geosciences, UiO for the financially support.

Thanks!