The 12th Gulf Water Conference
مؤتمر الخليج الثاني عشر للمياه

Impacts of Climate Change on Coastal Aquifers in Northern Oman

Ali Al-Maktoumi, PhD
Groundwater Hydrologist
Sultan Qaboos University, Oman

Outline

- Brief Overview of Literature
- Groundwater Models Jamma and SLC aquifers
- Climate Change Scenarios
- Results and Discussion
- Conclusions

Literature Review (Case studies)

- The level of negative impacts (changing of recharge patterns and sea level rise - SLR) depends on the level of stress the aquifer is experiencing. Shallow coastal aquifer are at greatest risk **(Danielopol et al., 2003; Holman, 2006; Kumar, 2012; and Werner at al., 2013).**
- **Sherif and Singh (1999)** investigated climate change effect on seawater intrusion coastal aquifers (Nile Delta aquifer in Egypt and Madras aquifer in India). The results show that a 0.5 m rise in the Mediterranean Sea level will cause additional intrusion of 9.0 km in the Nile Delta aquifer, but only 0.4 km in the Bay of Bengal (Madras aquifer).**[the impact is site specific and depends on the level of development that the aquifer experiences]**
- **Carneiro et al. (2010)** simulated effects of SLR and changes in recharge to the quantity and quality of groundwater on a coastal Saïdia aquifer in Morocco under three IPCC scenarios up to year 2099. They found that the freshwater volume reduced by 50 - 60 % with respect to the base condition, due to the decline in recharge (decrease in recharge).

Literature Review (Case studies)

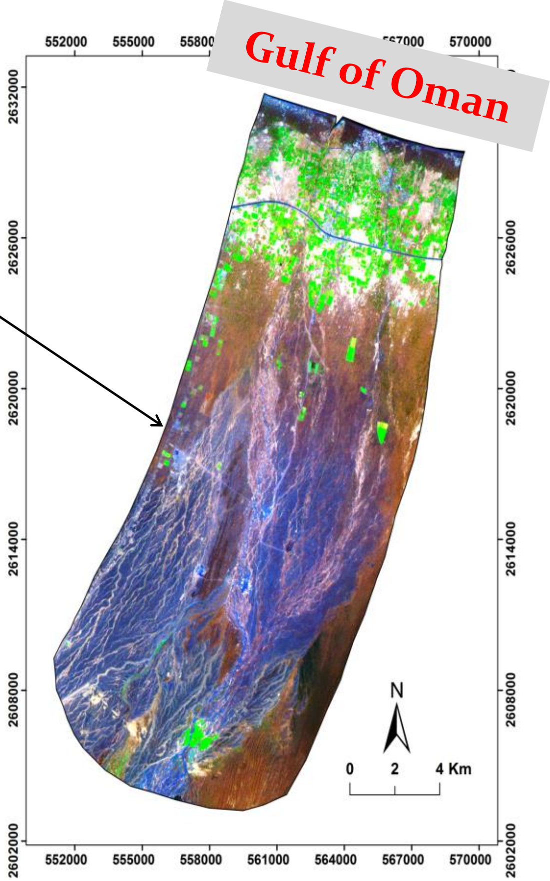
- A study by **<u>Ferguson and Gleeson (2012)</u>** found that coastal aquifers are more vulnerable to groundwater extraction than to predicted SLR under different cases of hydrogeologic conditions and population densities. Only aquifers with very low hydraulic gradients (seaward direction) are more vulnerable to SLR.

- Reviewing the literature shows that the effect of climate change on groundwater resources is a site specific based on geological and hydrological settings along with the level of development of the aquifer.

Jamma Aquifer and Samail Lower Catchement

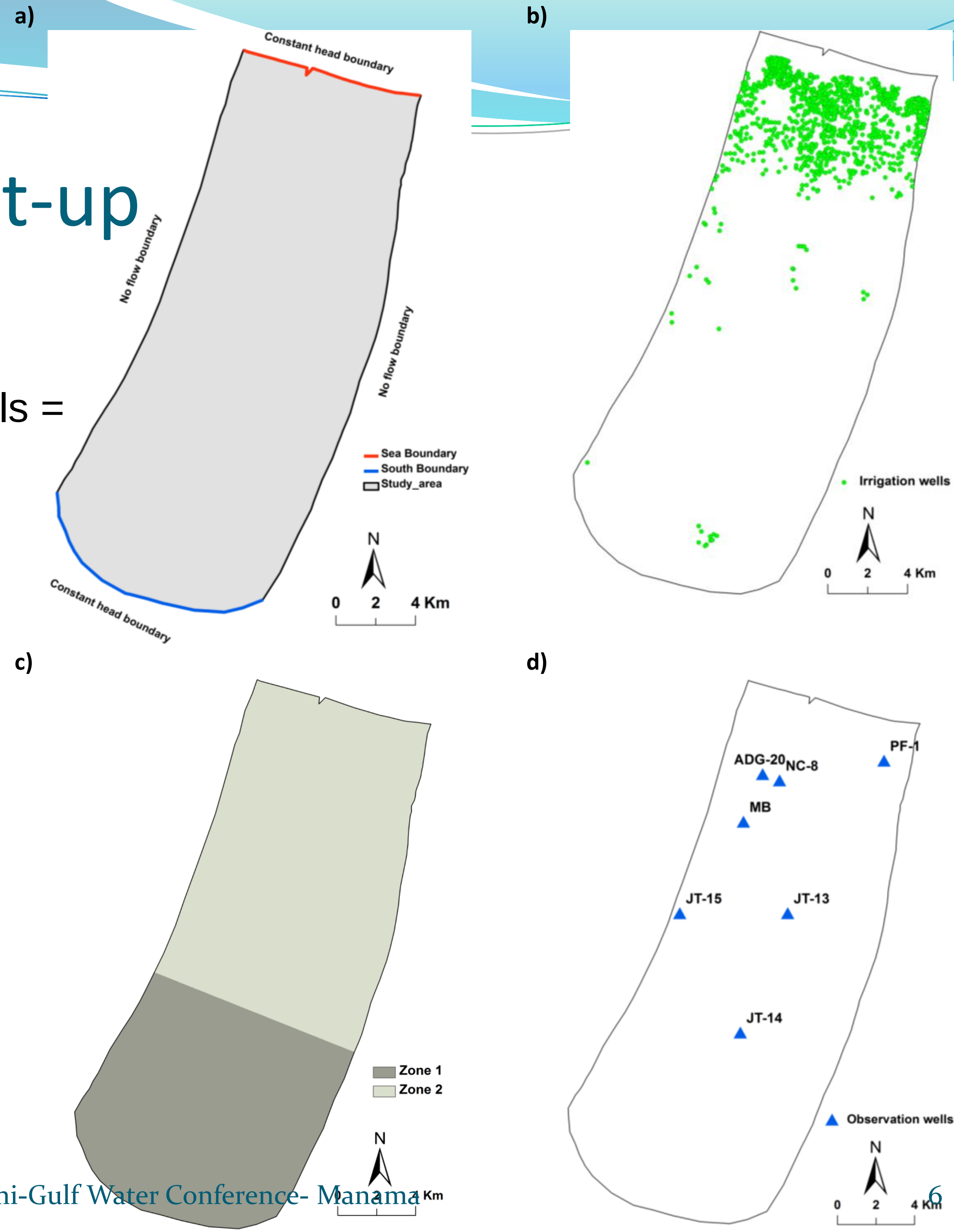
- Located on southeast Batinah- coast of Oman, about 50 km west of Muscat.
- Coastal plain part of Wadi Al Fara catchment(A= 295 km^2)
- Heavy abstraction, consequently seawater intrusion since early 1980.

Projected Coordinate System:
WGS 1984 UMT Zone 40N
Projection: Transverse Mercator
Centeral Meridian: 57.00
Latitude of Orgin:0.0
Source: Landsat



Jamma: Model Set-up

- Two layers, Δx, Δy =30 m.
- 952 rows and 610 columns.
- The total number of active cells = 655,390 cells.



(a) Boundary conditions
(b) Location of abstraction wells
(c) Hydraulic conductivity zones
(d) Location of observation wells

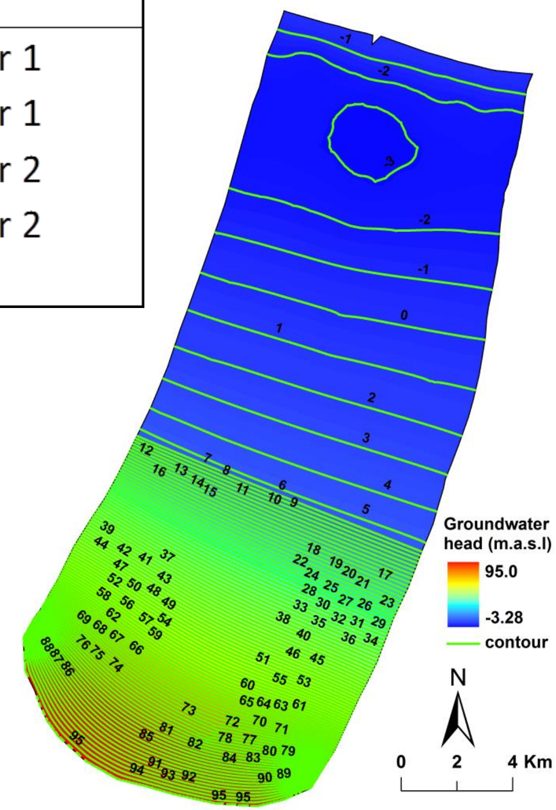
Jamma: Water balance and simulated heads for the base case (2015)

- The model performs well regardless the limitation of data availability.
- ME = -0.04 m, MAE = 0.9 m, and the model efficiency (NSE) is 0.96.

Parameter	Value (m/d)	Description
HKL1Z1	35	Hydraulic conductivity of Zone 1 in Layer 1
HKL1Z2	8	Hydraulic conductivity of Zone 2 in Layer 1
HKL2Z1	20	Hydraulic conductivity of Zone 1 in Layer 2
HKL2Z2	0.3	Hydraulic conductivity of Zone 2 in Layer 2
Rech	1.80247E-06	Recharge from precipitation

Water balance	In		Out		In - Out
	m^3/day	%	m^3/day	%	m^3/day
Inflow from sea	171,702	68.3	0	0	171,702
inflow from south	79,288	31.5	0	0	79,288
Pumping wells	0	0	243,695	97	-43,695
ET	0	0	7,829	3	-7,829
Recharge	534	0.2	0	0	534
Total	**251,524**	**100**	**251,524**	**100**	**0**

GW heads



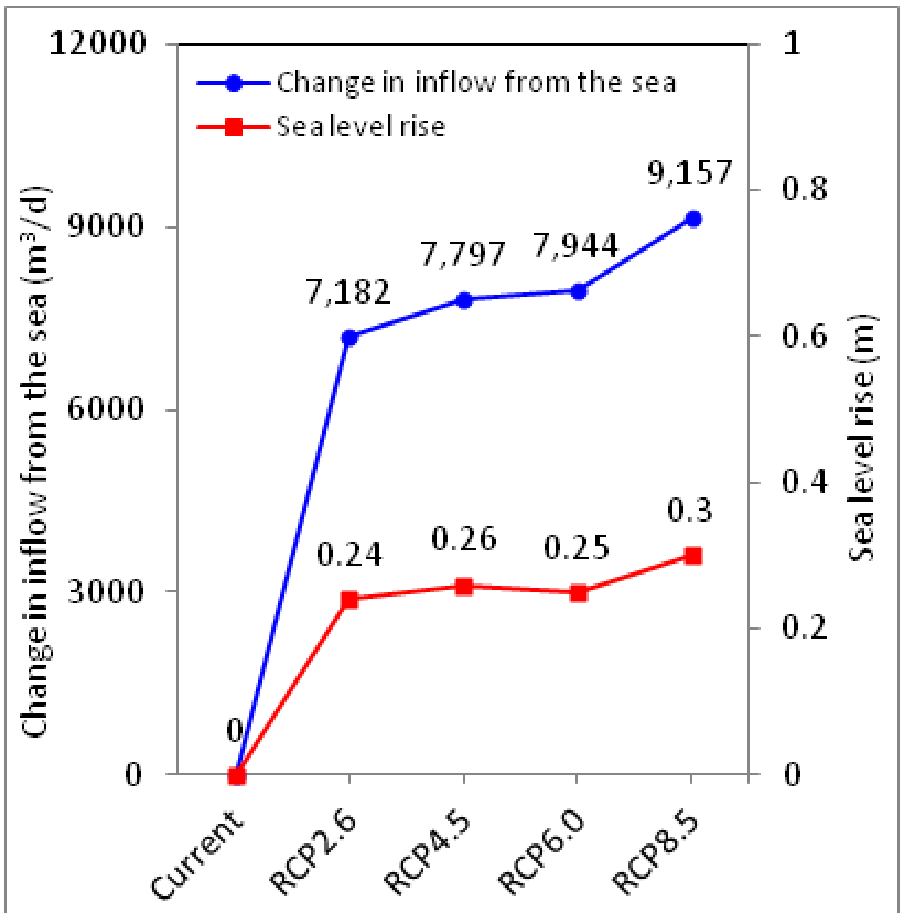
Jamma: Climate change and SLR data

	ET0		Precipitation		SLR	
	2050	2070	2050	2070	2050	2070
	mm/day		mm/year		m	
RCP2.6	7.15	7.15	81	83	0.24	0.4
RCP4.5	7.34	7.33	76	73	0.26	0.47
RCP6.0	7.50	7.57	81	83	0.25	0.48
RCP8.5	7.85	7.92	93	84	0.30	0.63

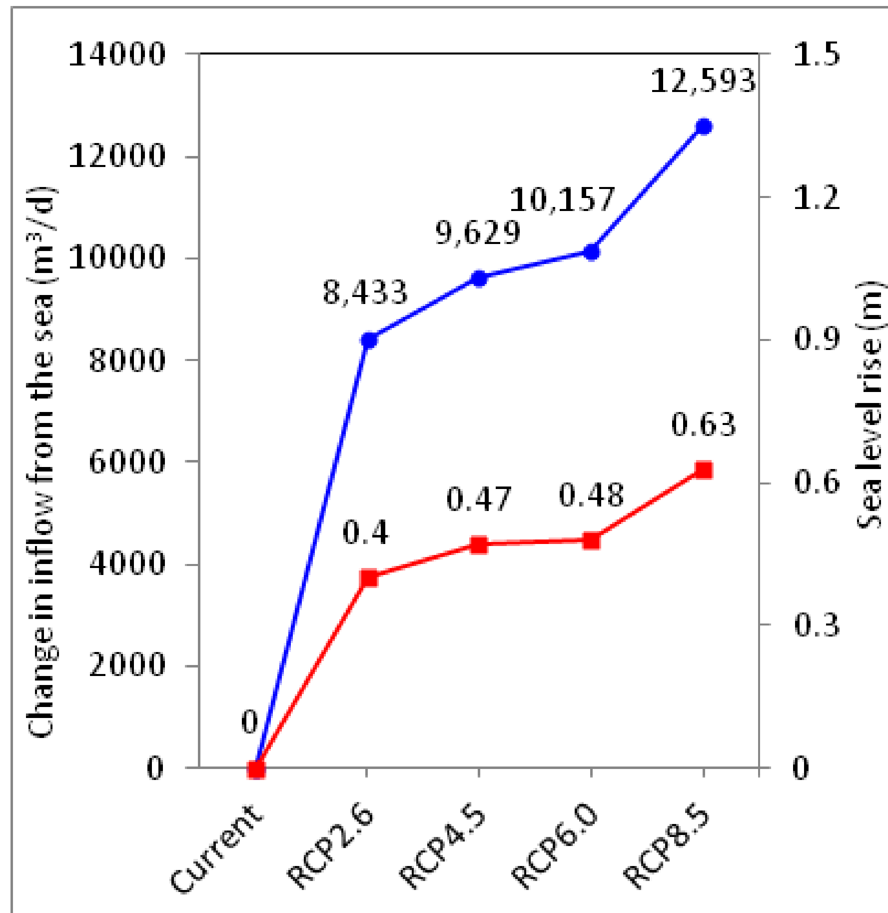
Note: *The evapotranspiration, precipitation and Sea level values of the* ***current case*** *are 4.5 mm/day, 60 mm/year and 0.0 m respectively.*

Jamma: Saline water inflow into the aquifer

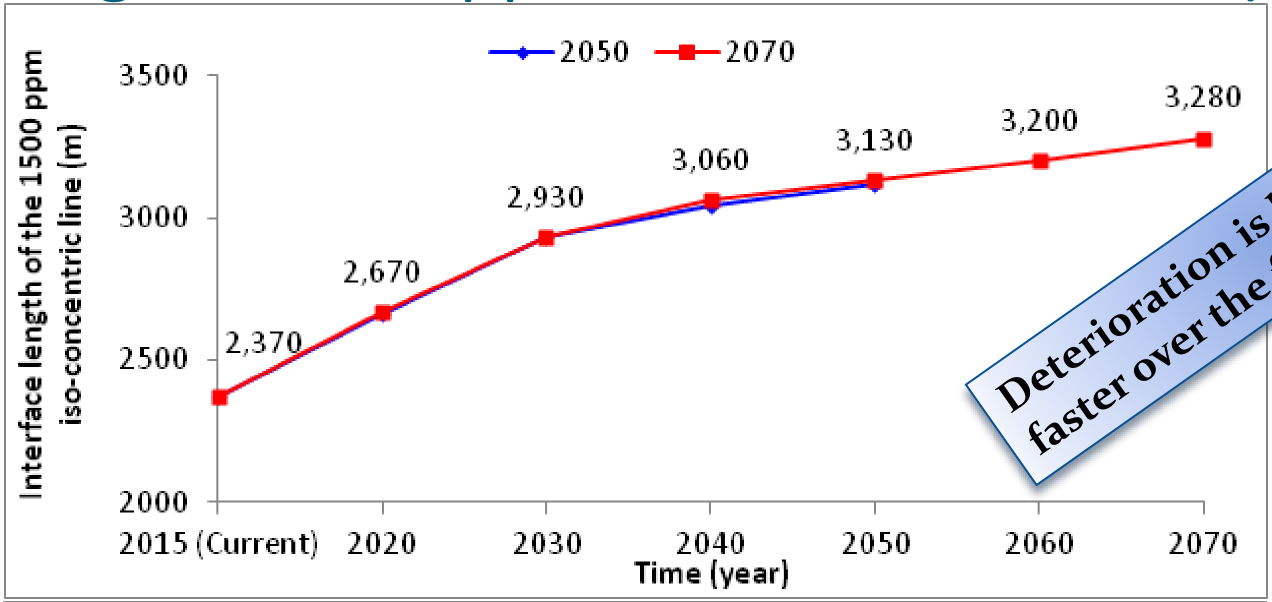
2050



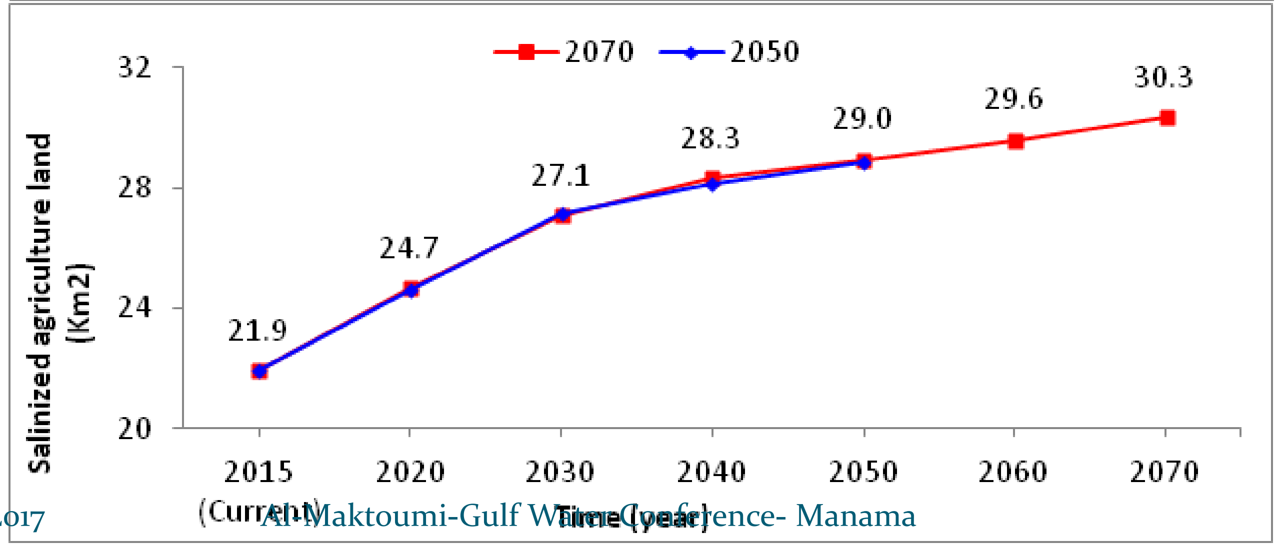
2070



Jamma: Intruded distance and salinized land area considering the 1500 ppm iso-concentric line (RCP8.5)

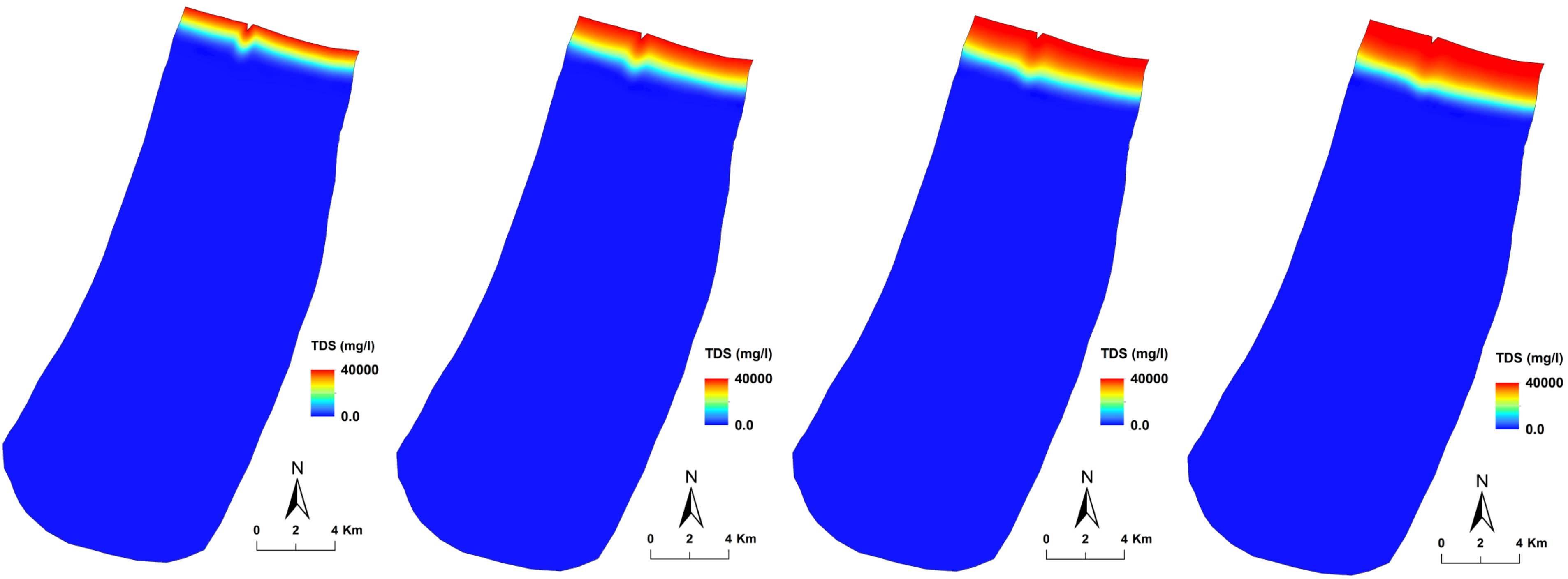


Deterioration is happening faster over the first 15 years

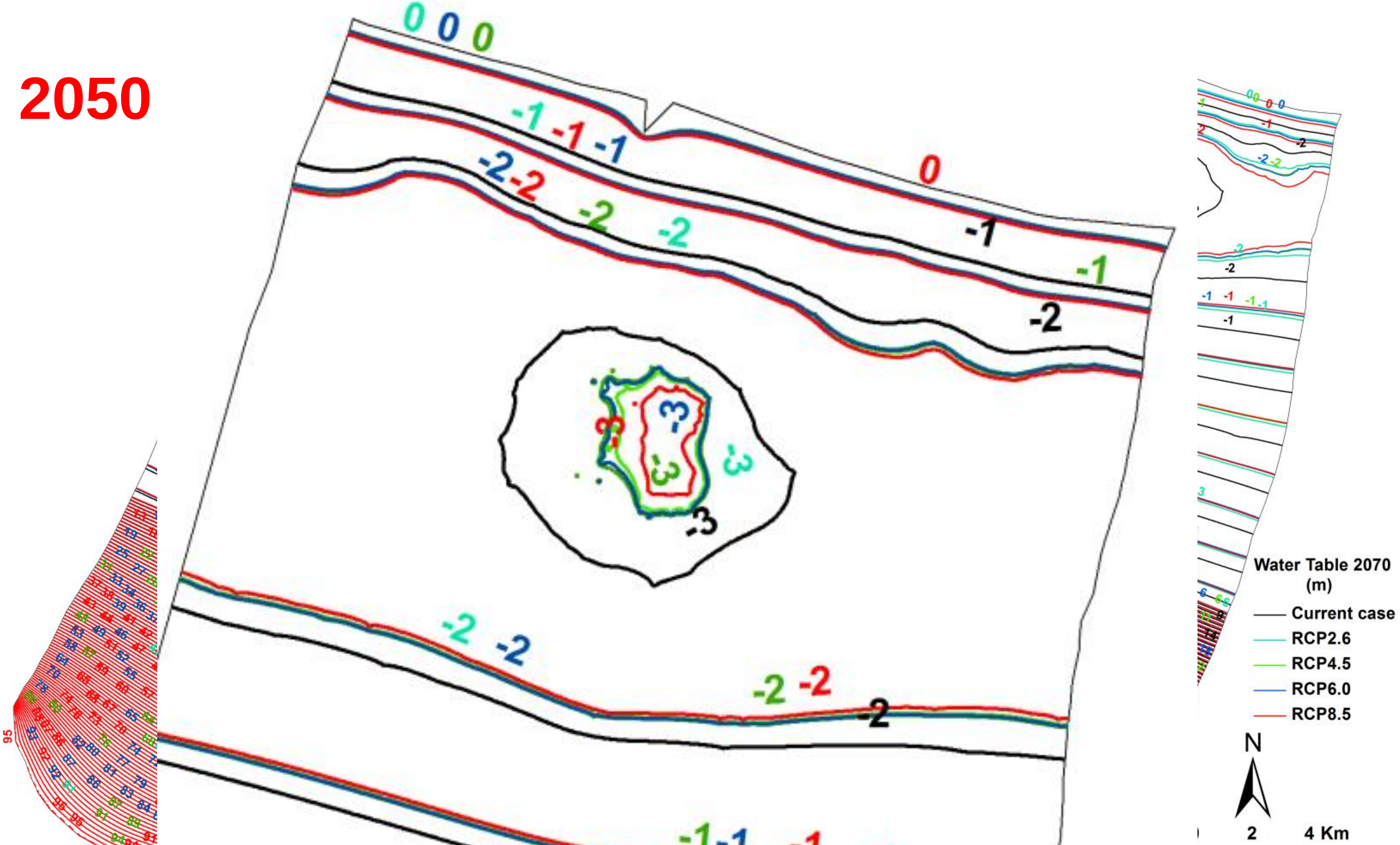


Jamma: Salinity maps for Jamma aquifer considering RCP8.5 (2070)

Current case | **2030** | **2050** | **2070**



Jamma: Water table contour maps for the current case and RCPs for 2050 and 2070



Consequences on the Farming Activities

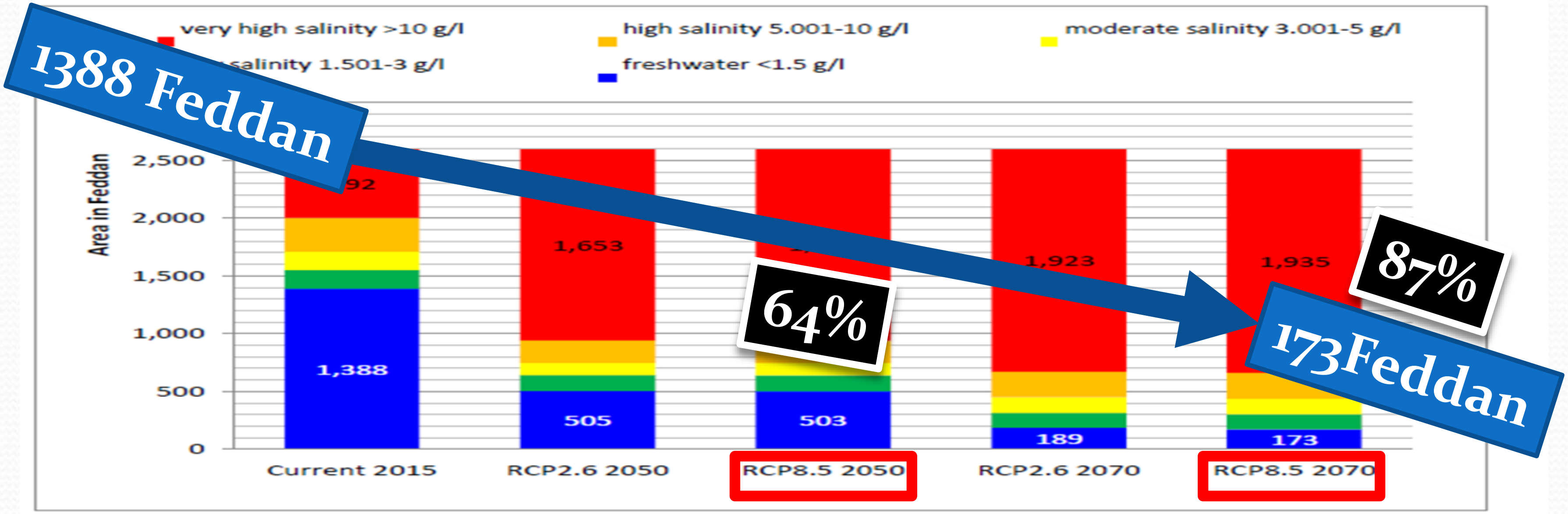


Figure 31: Agricultural area in Feddans overlying the aquifer according to the salinity of groundwater

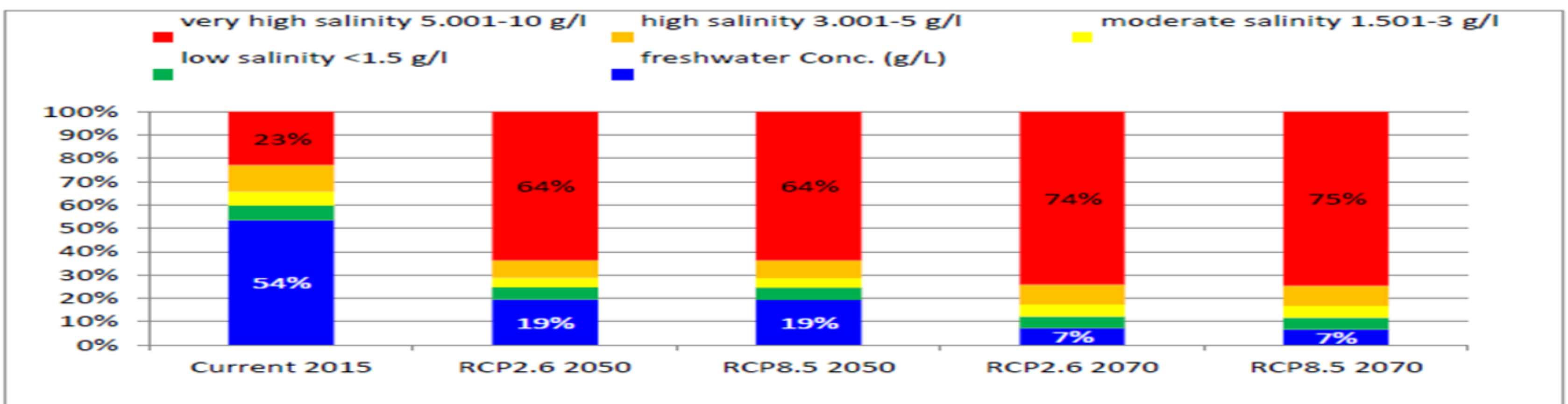


Figure 32: Agricultural area percentage wise overlying the aquifer according to the salinity of groundwater

Consequences on the Farming Activities, Cont'd

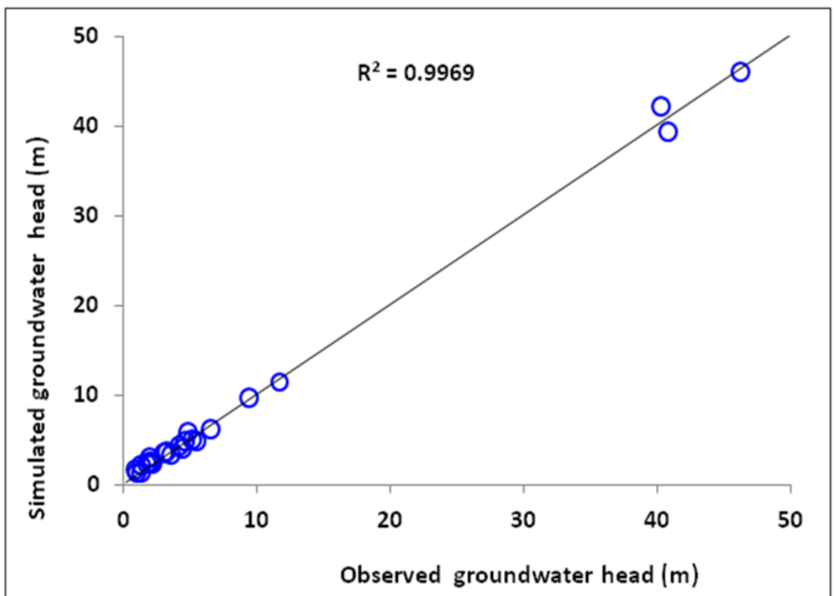
Gross profit in Rials per feddan according to salinity of the groundwater and area affected by salinity for the two climate change scenarios RCP2.6 and RCP8.5

	Salt Concentration in the groundwater in g/L	Gross Profit OR/Feddan	Cropped area in Feddans				
			Cropped area in 2015	RCP2.6 in 2050	RCP8.5 in 2050	RCP2.6 in 2070	RCP8.5 in 2070
freshwater	<1.5	1089	1,388	505	503	189	173
low salinity	1.501-3	803	164	137	137	128	130
moderate salinity	3.001-5	468	159	106	106	134	134
high salinity	5.001-10	431	292	194	193	221	224
very high salinity	>10	0	592	1,653	1,656	1,923	1,935
Total area in Feddan			2,595	2,595	2,595	2,595	2,595

- Gross profit/feddan is **1089 OR/feddan** on average for a farm accessing groundwater with **salinity lower than 1.5 g/L**
- Gross Profit goes down to **431 OR/feddan** if the groundwater salinity is comprised **between 5 and 10 g/L**.
- Beyond **10 g/L** there is no possibility to grow food crops and gross **profit is then nil** (OSS, 2012)

Samail Lower Catchment Aquifer

- Located in Al-Seeb area.
- Covers an area of 59 km^2
- Sensitivity analysis &calibration-PEST (32 piezometers).
- Calibrated results:
- Correlation coefficient (R2)= 0.99
- MAE = 0.63 m
- RMSE = 0.70 m



Projected coordinate System:
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Projection: Transverse Mercator
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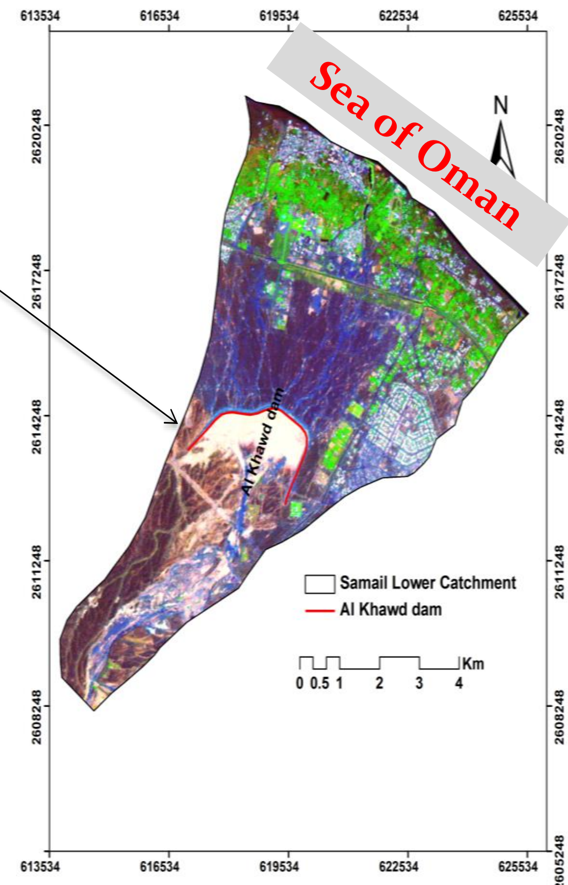
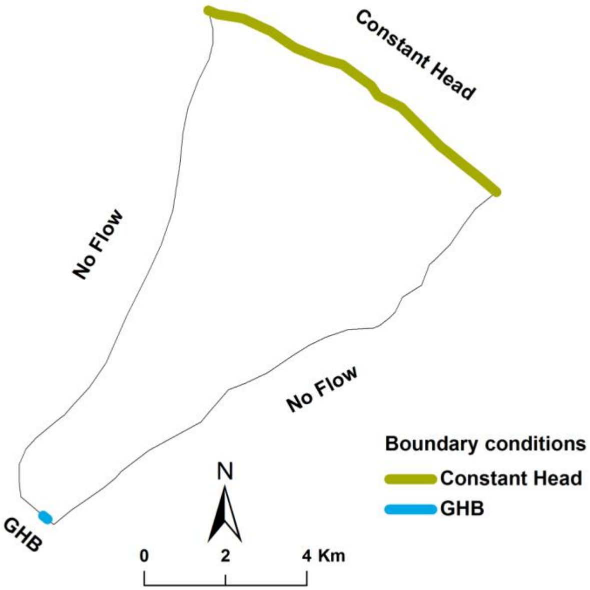
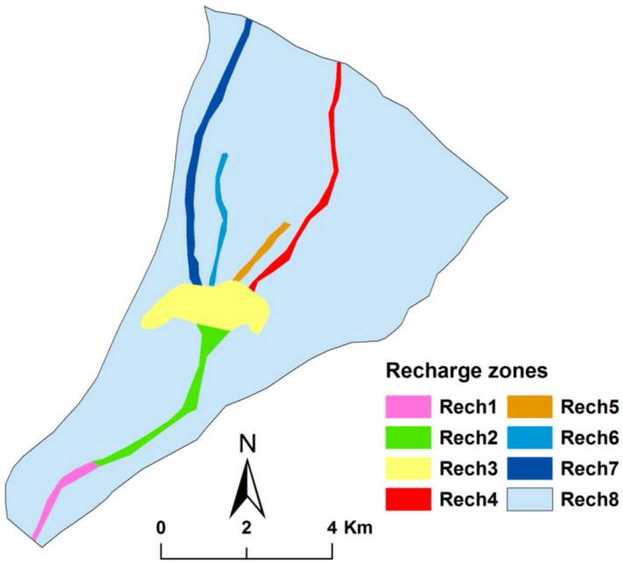
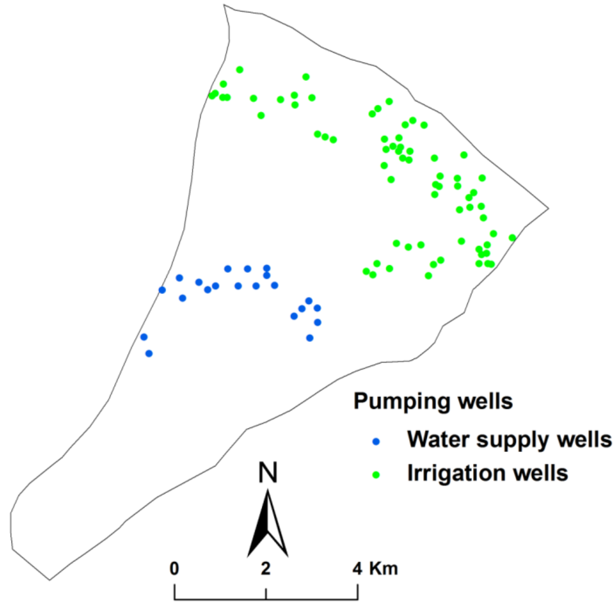
Latitude of Orgin = 0.0
Source: Landsat

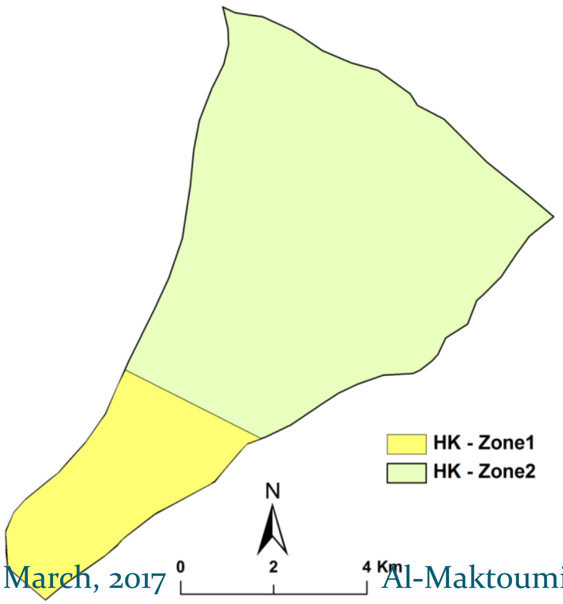


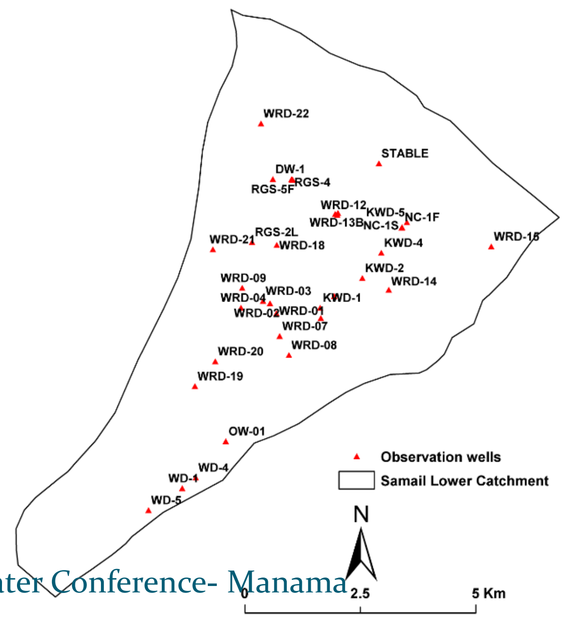
Samail: Model Set-up







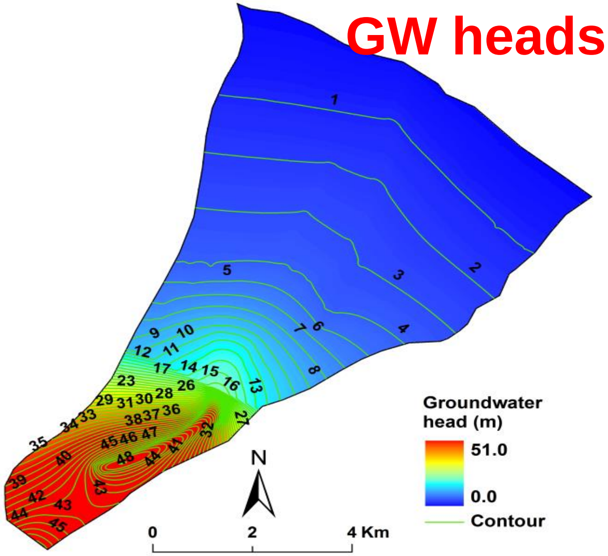




Samail: Water balance, simulated heads for base case, RCPs for the Samail Aquifer

Water balance

	In		Out		In - Out
	m^3/day	%	m^3/day	%	m^3/day
Constant head	413	1	12,833	30	-12,420
Pumping wells	0	0	21,343	49	-21,343
ET	0	0	9,067	21	-9,067
GHB	886	2	0		886
Recharge	41,944	97	0	0	41,944
Total	**43243**	**100**	**43243**	**100**	**0**



	ET0		**Precipitation**		**SLR**	
	2050	**2070**	**2050**	**2070**	**2050**	**2070**
	mm/day		mm/year		m	
RCP2.6	7.15	7.15	80	91	0.24	0.4
RCP4.5	7.34	7.33	82	77	0.26	0.47
RCP6.0	7.5	7.57	87	90	0.25	0.48
RCP8.5	7.85	7.92	98	88	0.3	0.63

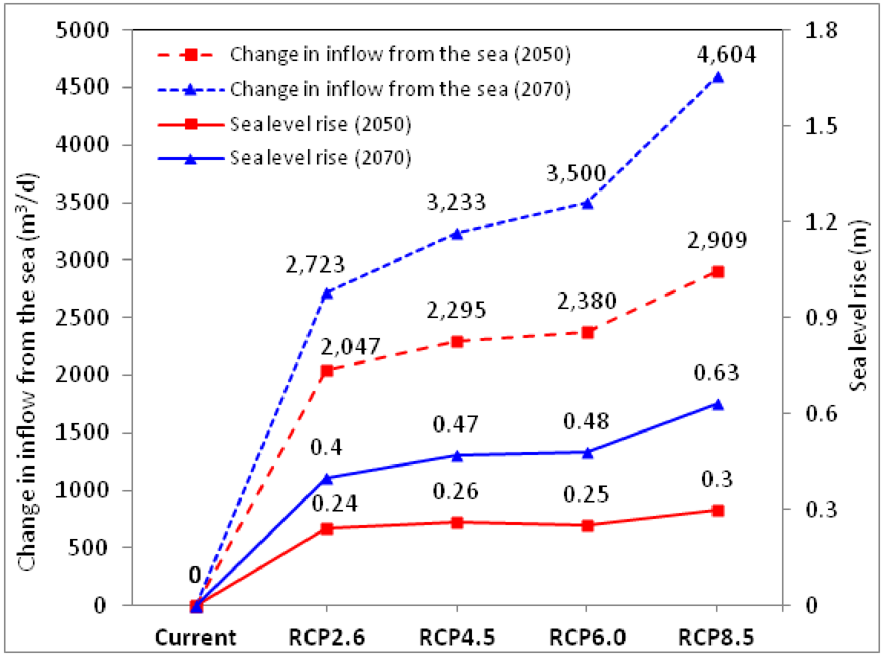
Note: *Base case (2015):*

ET= ***5 mm/day***

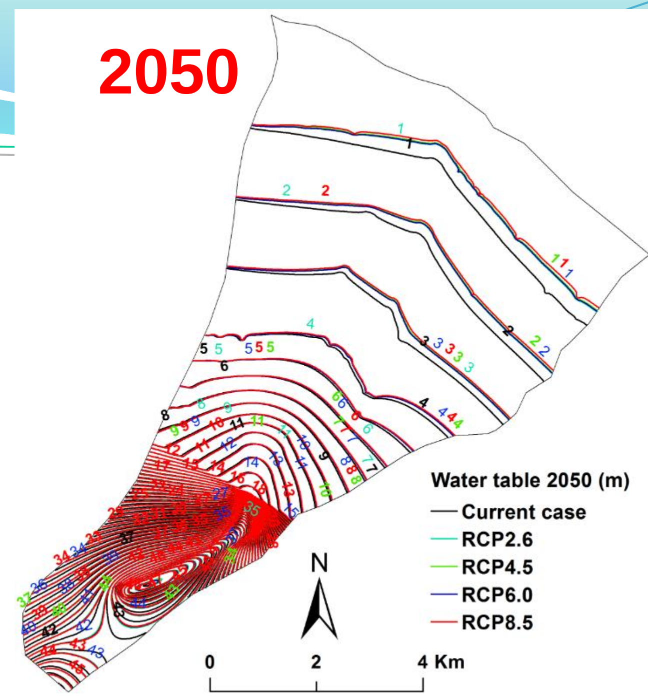
Precipitation = ***80 mm/year***

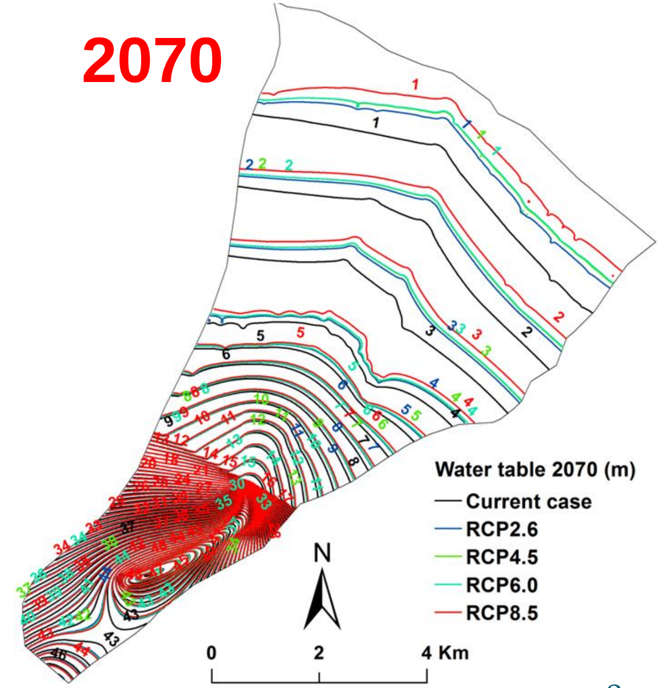
Sea level values = ***0***

Samail: Inflow across coastal boundary, hydraulic head contour maps



- Change in precipitation is small
- Effect of pristine groundwater flow





Conclusions

- **The extent of the effect of climate change on groundwater aquifer is site specific.** Stressed aquifers are highly vulnerable and severely affected. A need to categorize the aquifers in different groups to plan the mitigation tasks accordingly
- The impact of the climate change **is happening at rapid rate during the first few years** which necessitate that mitigation actions have to be implemented as early as possible. Otherwise, late implementation will be less effective in mitigating the depleted resources and deteriorated quality which will definitely affects the farming community in large along with other purposes.
- Sea level rise found to be the **main factor that significantly affects the coastal groundwater resources.** This is because the change in rainfall rate as per the RCPs scenarios for north of Oman is small and the effect of ET is also low because of high extinction depth.
- Although, the aquifer systems that maintains a positive hydraulic gradient seaward direction (like SLC in this study) is not severely affected by the climate change, but improper development and management of those systems **would definitely shift them to be more vulnerable to be adversely effected by climate change**

Acknowledgement

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