Soil salinization and degradation in the Tarim basin

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Dec. 2015

1. Introduction

- The Tarim River Basin, the most important location for Chinese cotton production as a result of exploitation gained attention (serious degradation of soil; increased water salinity; water resource degradation and plant coverage reduction).
- Through reduced matric potential the water use effenciency is increased in cotton cultivation with plastic mulching and drip irriagtion.
- The soil texture and structure, organic matter content, bulk density, salt content of soils effect the water retention in arid and semi-arid areas.




2. Material and Methods

2.1 sampling location

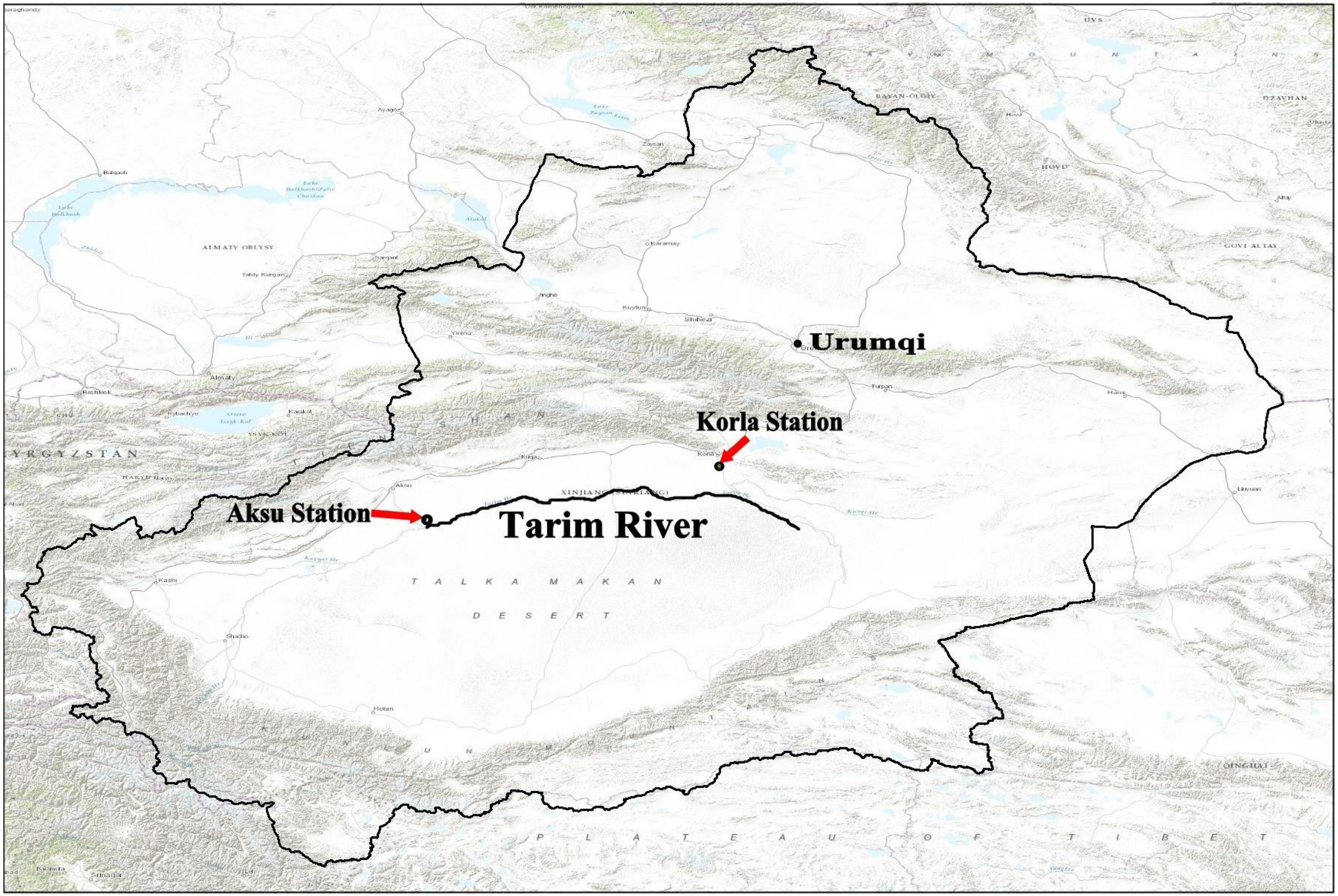

Fig. 1 Location of the Aksu (left arrow) and Korla (right arrow) experimental stations in Tarim River Basin.

2. Material and methods

2.2 Field experimental design

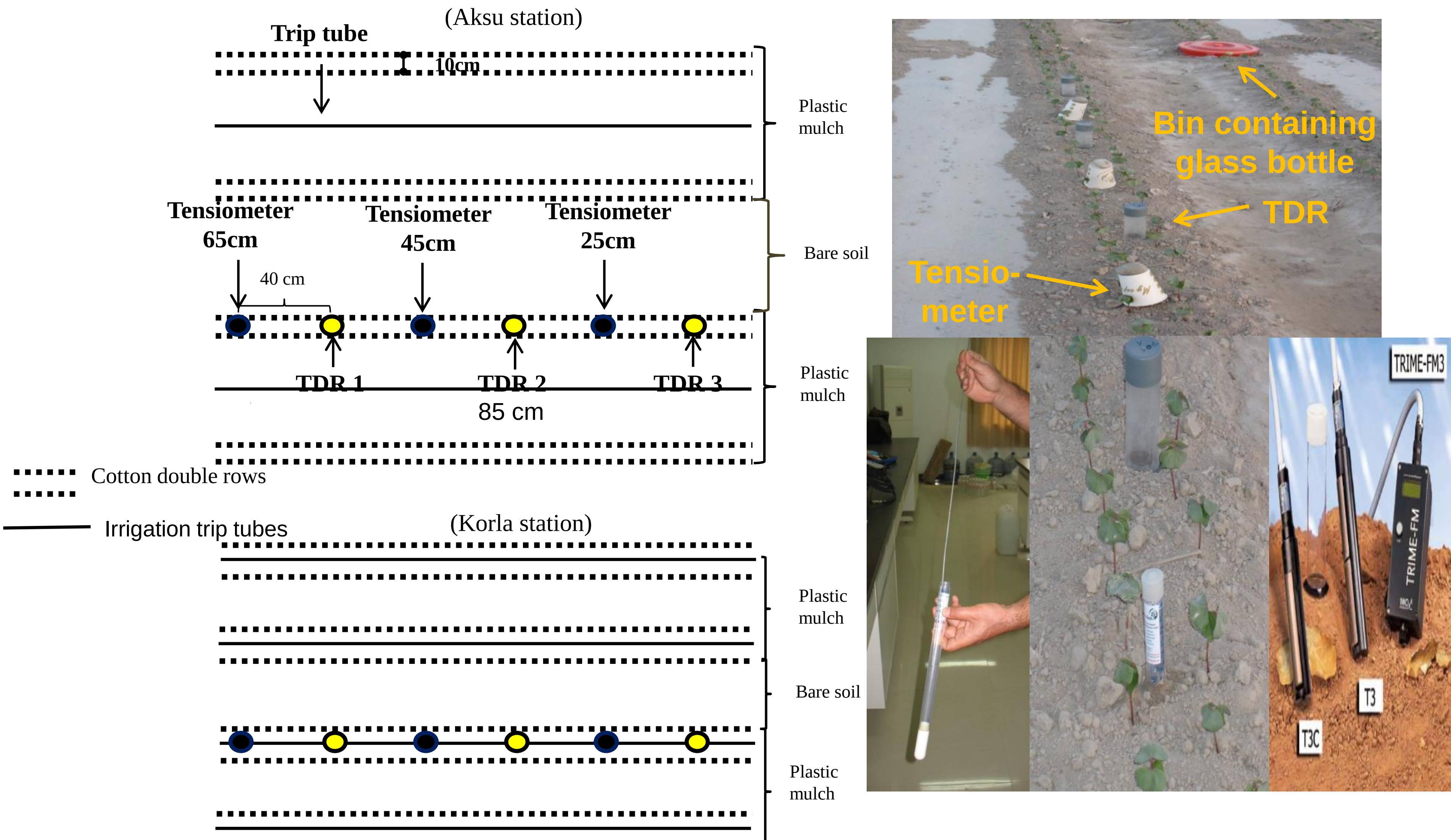

Fig. 2 Field experimental design in different saline soils during cotton season from May to September 2012 in Aksu and Korla.

2. Material and Methods

2.3 Calculation

1. $\psi_T = \psi_M + \psi_O + \psi_P + \psi_Z$

2. $ECe = (14.0 - 0.13 \times \text{clay }\%) \times EC_{1:5}$

3. $\psi_O = -0.036 EC_{meas}\ \theta_{ref}/\theta_{act}$

4. $ETc = I + P \pm \Delta S - R - D$

5. Cotton seed yield = plant density × average capsule number per cotton plant × weight per capsule × 85%

6. Average capsule number per cotton plant = capsule with cotton + capsule without cotton+1/3 × small capsule (smaller than 2 cm)

7. $WUE = Y/ET_C$

8. $IWUE = Y/I$

ψ_T: the total soil water potential; ψ_M : the matric potential; ψ_O: the osmotic potential; ψ_P: the pressure potential ; ψ_Z: the gravitational potential; EC_{meas}: the measured electrical conductivity ($mS \cdot cm^{-1}$) of the extract at the reference water content (1:5 soil/water mixture); θ_{ref}: the reference water content ($g\ g^{-1}$) at 1:5 soil/water mixture; θ_{act}: the actual moisture content ($g\ g^{-1}$) ; Etc: The total cotton evapotranspiration; I: the irrigation amount; P: the precipitation; ΔS: the change of soil water storage in 1m; R: the surface runoff; D: the downward flux below the crop root zone; Y: yield ($t\ ha^{-1}$); I: irrigation water amount.

2. Material and Methods

2.4 Basic information of two experimental stations

Site	Location	Temp (℃)	Prec (mm)	Ele (m)	GWD (m)	Relative humidity[a] (%)	Wind speed[a] (km h^{-1})	Soil type
Aksu	40° 37N 80° 45´E	11.0	71.6	1028	2.0	50.5	5.3	Solonchak
Korla	41° 35´N 86° 09´E	12.2	100.8	903	1.4	42.8	7.7	Solonchak

Temp, annual average temperature from 1982-2012.
Prec, annual total precipitation from 1982-2012.
Ele, elevation.
GWD, groundwater depth.
[a] the annual average data from 1982-2012.

3.1 Soil chemical and physical properties

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Soil salinity Level		Sample Depth	CEC	BD	pH_{H2O} (1:5)	EC (1:5)	ECe	Partial size distribution			Soil texture
								Clay	Silt	Sand	
		(cm)	(cmol/kg)	(g/cm^3)		(mS·cm^{-1})		(%)			
Low (17-25 mS·cm^{-1})	Low (Korla)	27	2.9	1.57	7.8	1.7	23.8	2.1	32.5	65.5	Sal
		52	2.0	1.55	8.1	1.5	21.0	9.7	82.3	8.10	Sl
		63	1.5	1.50	8.2	1.5	21.0	4.7	73.7	21.6	LS
		85	2.9	1.56	8.2	1.8	25.2	3.4	54.1	42.6	Sl
		120	1.2	1.50	8.5	1.2	16.8	6.4	64.5	29.1	LS
		140	1.9	1.57	8.4	1.3	18.2	8.1	89.2	2.7	Sl
	Low (Aksu)	27	5.0	1.37	8.0	1.8	25.2	6.1	82.1	11.8	Silt
		38	7.4	1.54	8.2	1.4	19.6	4.8	80.6	14.6	Sl
		64	6.1	1.51	8.1	1.5	21.0	7.9	66.4	25.7	Sl
		130	1.7	1.33	8.3	1.2	16.8	5.2	61.4	33.3	Sl
Middle (29-50 mS·cm^{-1}) (Aksu)		35	5.6	1.52	7.5	3.5	49.0	5.4	74.7	19.9	Sl
		67	1.8	1.42	7.5	3.6	50.4	2.6	51.1	46.3	Sl
		104	5.5	1.40	7.9	2.1	29.4	3.6	70.8	25.5	Sl
		130	4.8	1.48	7.9	1.6	22.4	4.5	75.1	20.4	Sl
High (52-62 mS·cm^{-1}) (Aksu)		32	2.8	1.70	7.5	3.7	51.8	4.0	57.5	38.5	Sl
		57	2.8	1.71	7.6	4.1	57.4	4.7	68.5	26.8	Sl
		85	3.8	1.39	7.6	4.4	61.6	5.1	74.6	20.3	Sl
		110	3.9	1.49	7.5	4.3	60.2	6.7	81.7	11.6	Silt
		115	4.1	n.d.	7.4	4.2	58.8	5.6	78.7	15.7	Sl

3. Result

3.1 Soil chemical and physical properties (to be continued)

Soil salinity Level		Sample Depth (cm)	C_{org}	N_{tot}	$CaCO_3$	CO_3^{2-}	HCO_3^-	Cl^-	SO_4^{2-}	Ca^{2+}	Mg^{2+}	Na^+	K^+
			(g/kg)										
Low (17-25 mS·cm^{-1})	Low (Korla)	27	4.8	1.1	116.1	0.00	0.2	0.2	2.1	0.8	0.2	0.2	0.1
		52	1.7	0.9	123.5	0.00	0.3	0.4	0.6	0.3	0.1	0.3	0.1
		63	1.6	0.9	120.7	0.00	0.2	0.2	0.9	0.4	0.1	0.2	0.1
		85	2.4	0.9	115.9	0.01	0.3	0.6	1.2	0.4	0.2	0.5	0.1
		120	1.5	0.9	111.1	0.01	0.3	0.2	0.4	0.2	0.1	0.2	0.1
		140	2.1	0.9	116.5	0.01	0.2	0.2	0.4	0.2	0.1	0.2	0.1
	Low (Aksu)	27	6.8	1.3	161.4	0.01	0.4	0.3	1.6	0.5	0.3	0.3	0.1
		38	8.7	1.4	157.1	0.00	0.4	0.2	0.7	0.3	0.1	0.2	0.1
		64	8.2	1.4	159.8	0.00	0.4	0.2	0.8	0.3	0.2	0.2	0.1
		130	2.1	0.9	67.1	0.00	0.3	0.2	0.3	0.2	0.1	0.1	0.1
Middle (29-50 mS·cm^{-1}) (Aksu)		35	4.4	0.3	138.7	0.00	0.1	0.5	8.2	2.5	0.3	0.8	0.1
		67	1.5	0.1	94.8	0.00	0.1	1.0	8.1	2.9	0.1	0.9	0.0
		104	2.2	0.2	161.7	0.00	0.2	0.8	1.4	0.3	0.1	0.7	0.0
		130	2.1	0.1	170.6	0.00	0.2	0.2	1.2	0.2	0.1	0.3	0.0
High (52-62 mS·cm^{-1}) (Aksu)		32	2.1	0.1	100.4	0.00	0.1	1.0	8.3	2.7	0.3	1.0	0.1
		57	1.5	0.1	108.5	0.00	0.1	1.7	8.9	2.9	0.3	1.5	0.1
		85	1.8	0.1	107.9	0.00	0.1	2.1	8.8	2.8	0.3	1.9	0.0
		110	1.7	0.1	138.1	0.00	0.1	1.9	8.5	2.8	0.2	1.8	0.0
		115	1.7	0.1	121.9	0.00	0.1	1.7	8.7	2.9	0.1	1.8	0.0

Sal: sandy loam; Sl: silt loam

3. Result

3.2 Soil water content

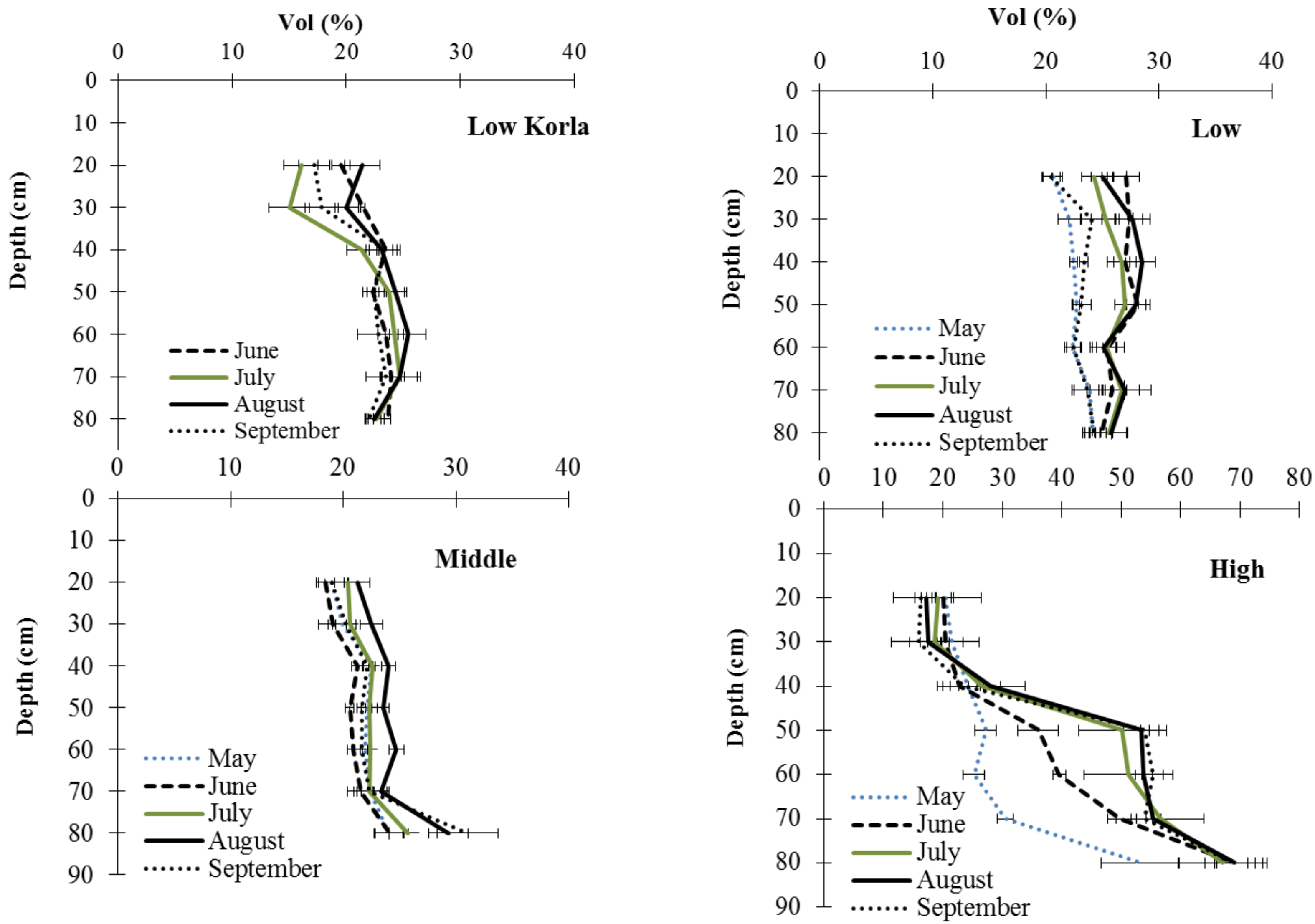


Fig. 3 Soil water content in different saline (low Korla ,low, middle, high) soils in depths (0-80cm) during cotton season from May to September 2012 in Tarim River Basin.

3. Result
3.3 Soil matric suction

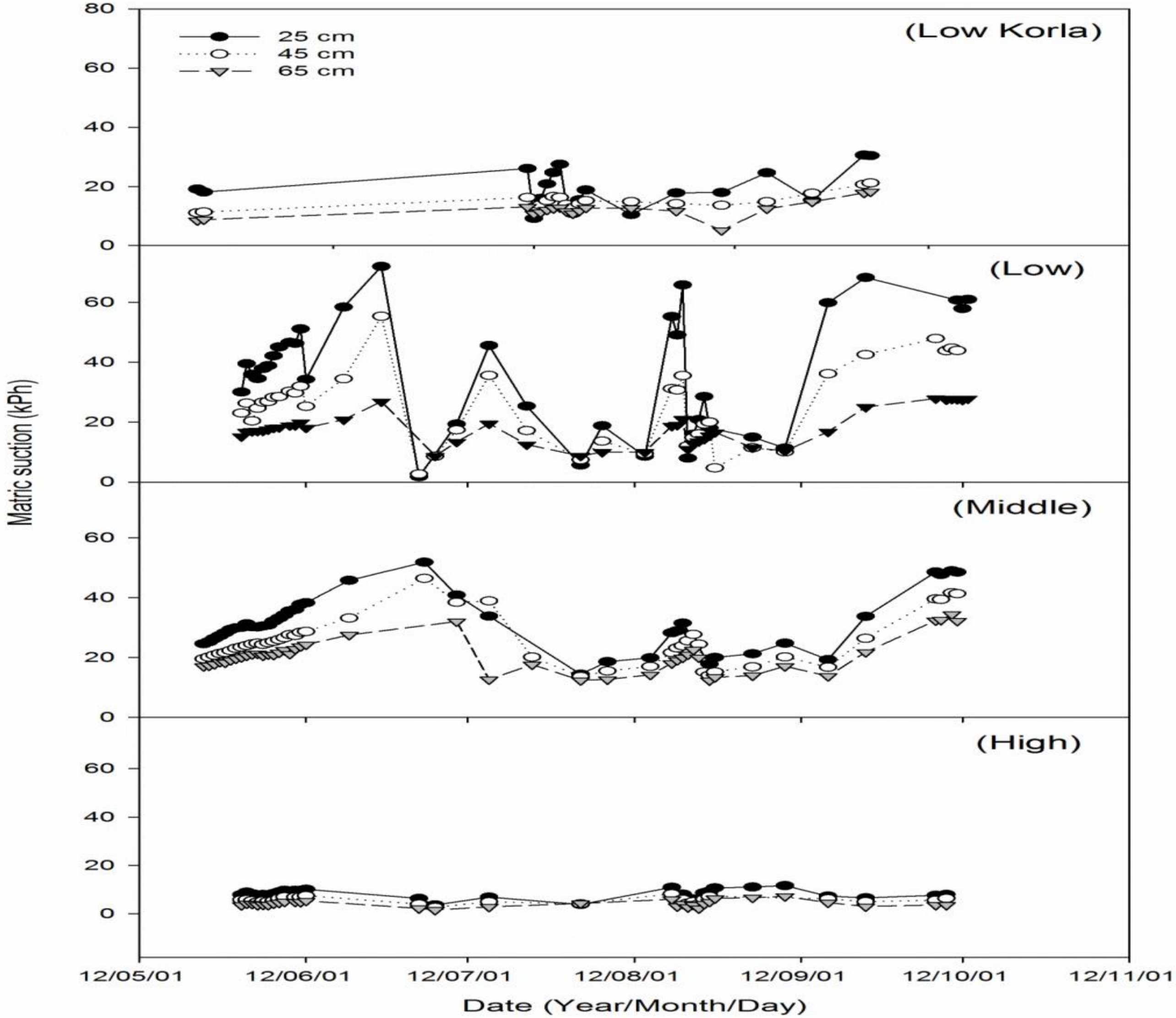


Fig. 4 Soil matric suction in different saline (low Korla, low, middle, high) soils in depths (25cm, 45, 65cm) during cotton season from May to October 2012 in Tarim River Basin.

3. Result

3.3 The Soil Water Characteristic Curves (Matric suction)

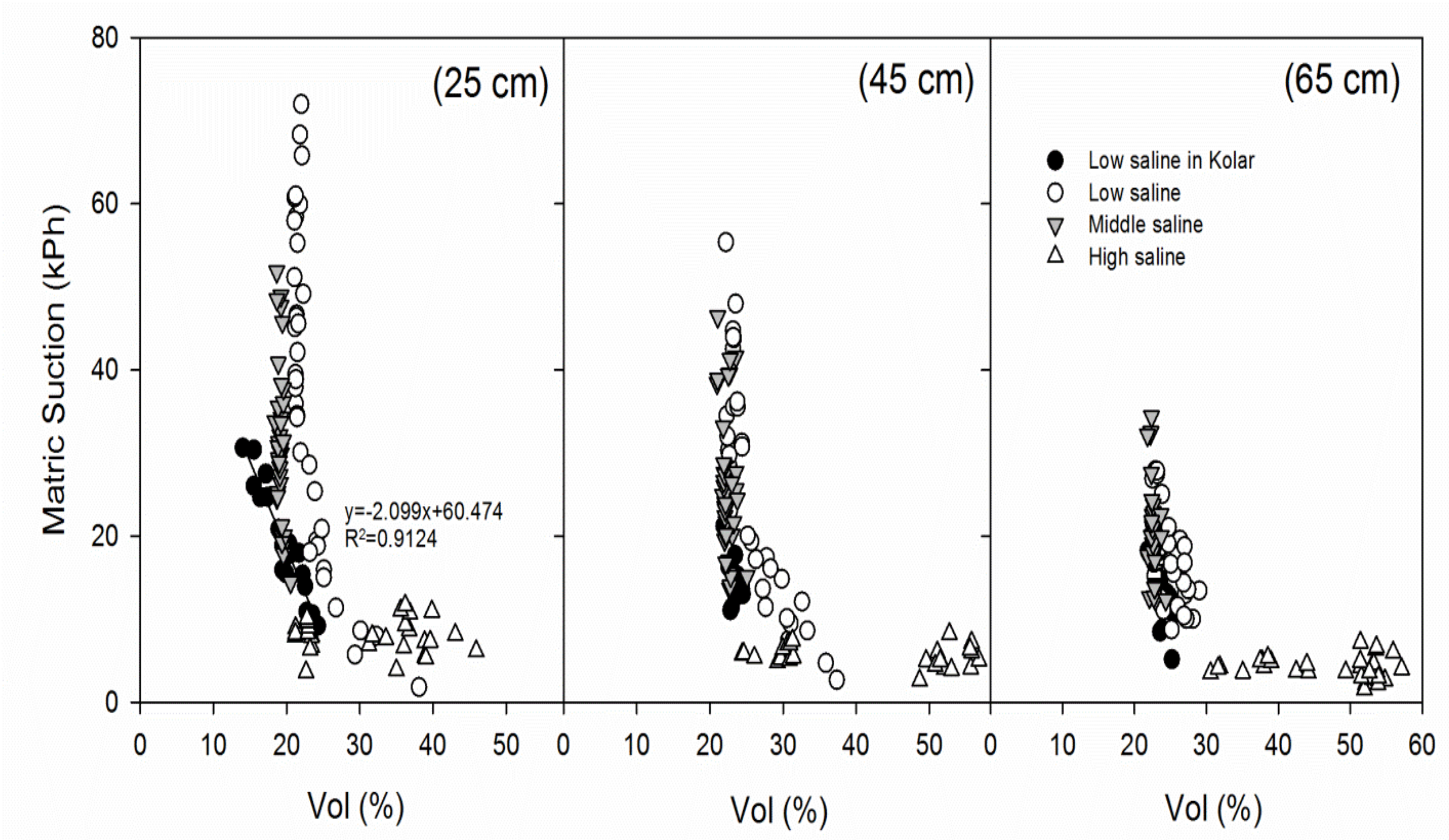


Fig. 5 The Soil Water Characteristic Curves (Matric suction) of different saline soils in depths (25cm, 45cm, 65cm) during cotton season from May to September 2012 in Tarim Basin.

3.3 The Soil Water Characteristic Curves (matric and osmotic suction)

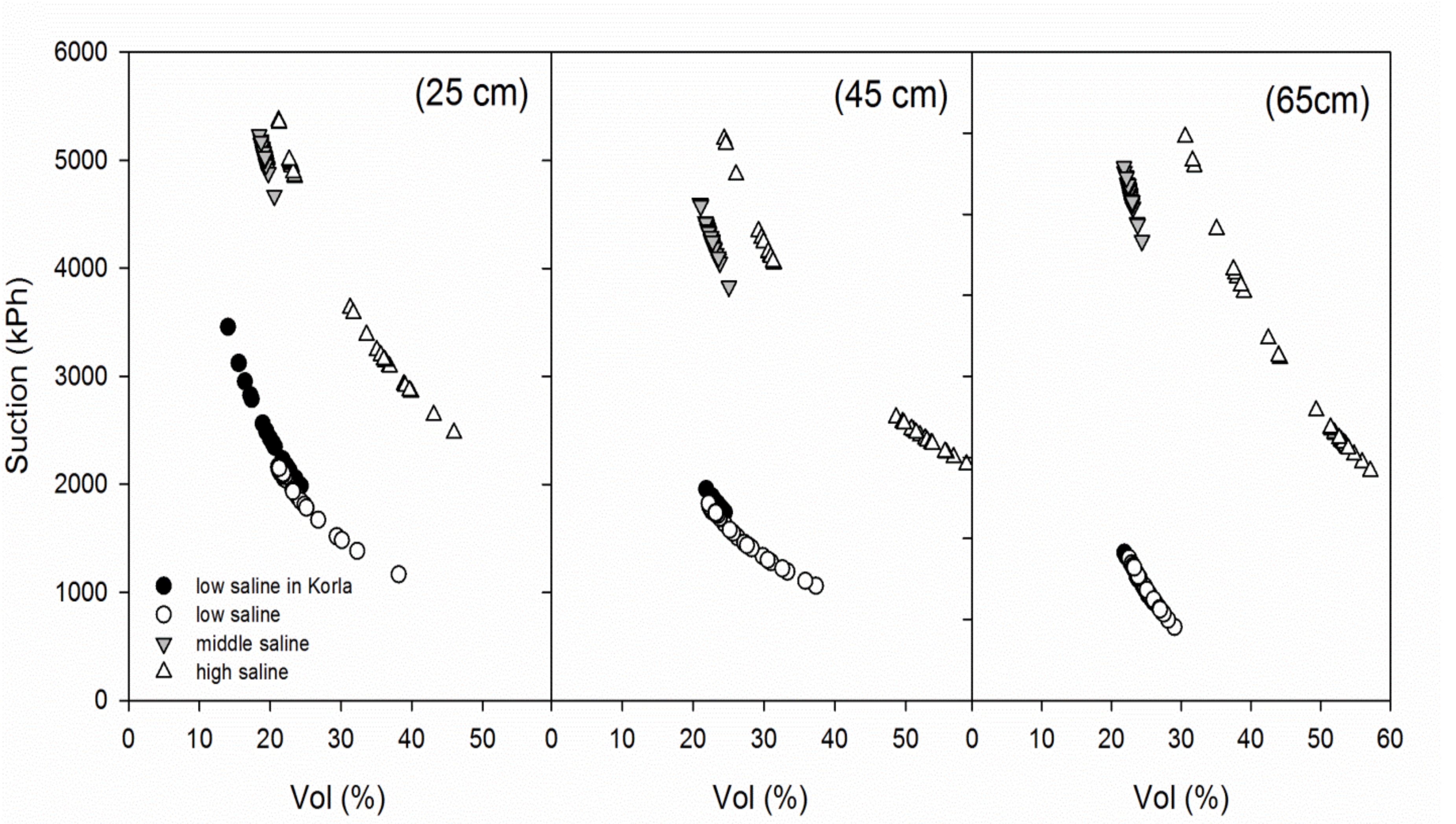


Fig. 5 The Soil Water Characteristic Curves (matric and osmotic suction) of different saline soils in depths (25cm 45cm, 65cm) during cotton season from May to September 2012 in Tarim Basin.

3. Result

3.4 The field management data and water use efficiency

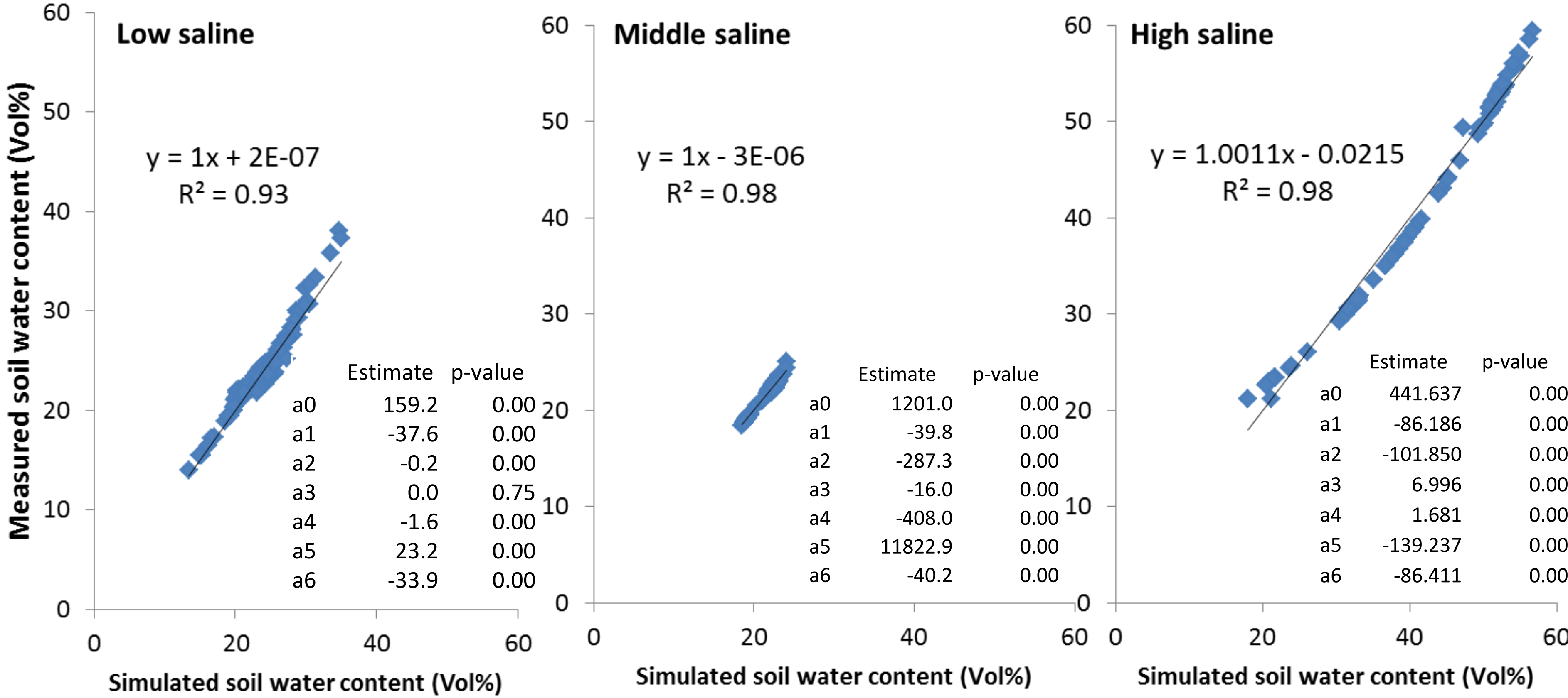
Location	Soil salinity	Sowing	Harvest	Fert_N	Fert_P	Fert_K	Irrigation[a]	Precipitation[a]	Yield[b]	IWUE	WUE
	Level	date	date	(kg N ha^{-1})	(kg P ha^{-1})	(kg K ha^{-1})	(mm)	(mm)	(t ha^{-1})	(t ha^{-1} mm^{-1})	
Korla	Low	04.05	04.09	331	124	108	571	128	6.64	0.012 [a]	0.010[a]
Aksu	Low	08.04	15.09	306	294	55	878	49	4.48	0.005 [b]	0.005[b]
Aksu	Middle	25.04	10.09	317	88	135	878	49	4.68	0.005 [b]	0.005[b]
Aksu	High	08.04	05.09	327	215	70	804	49	2.39	0.003[c]	0.003[c]

[a] the amount was within the growth season. [b] cotton seed yield.
IWUE, irrigation water use efficiency; WUE, water use efficiency;
Values in the same column followed by the different letters indicate significant differences among treatments at 0.05 level

3. Result

3.5 The water retention modelling

$$Vol\% = a0 + a1*pF1 + a2*clay\% + a3*silt\% + a4*C_{org} + a5*N_{tot} + a6*pF2$$



Low saline:

	Estimate	p-value
a0	159.2	0.00
a1	-37.6	0.00
a2	-0.2	0.00
a3	0.0	0.75
a4	-1.6	0.00
a5	23.2	0.00
a6	-33.9	0.00

Middle saline:

	Estimate	p-value
a0	1201.0	0.00
a1	-39.8	0.00
a2	-287.3	0.00
a3	-16.0	0.00
a4	-408.0	0.00
a5	11822.9	0.00
a6	-40.2	0.00

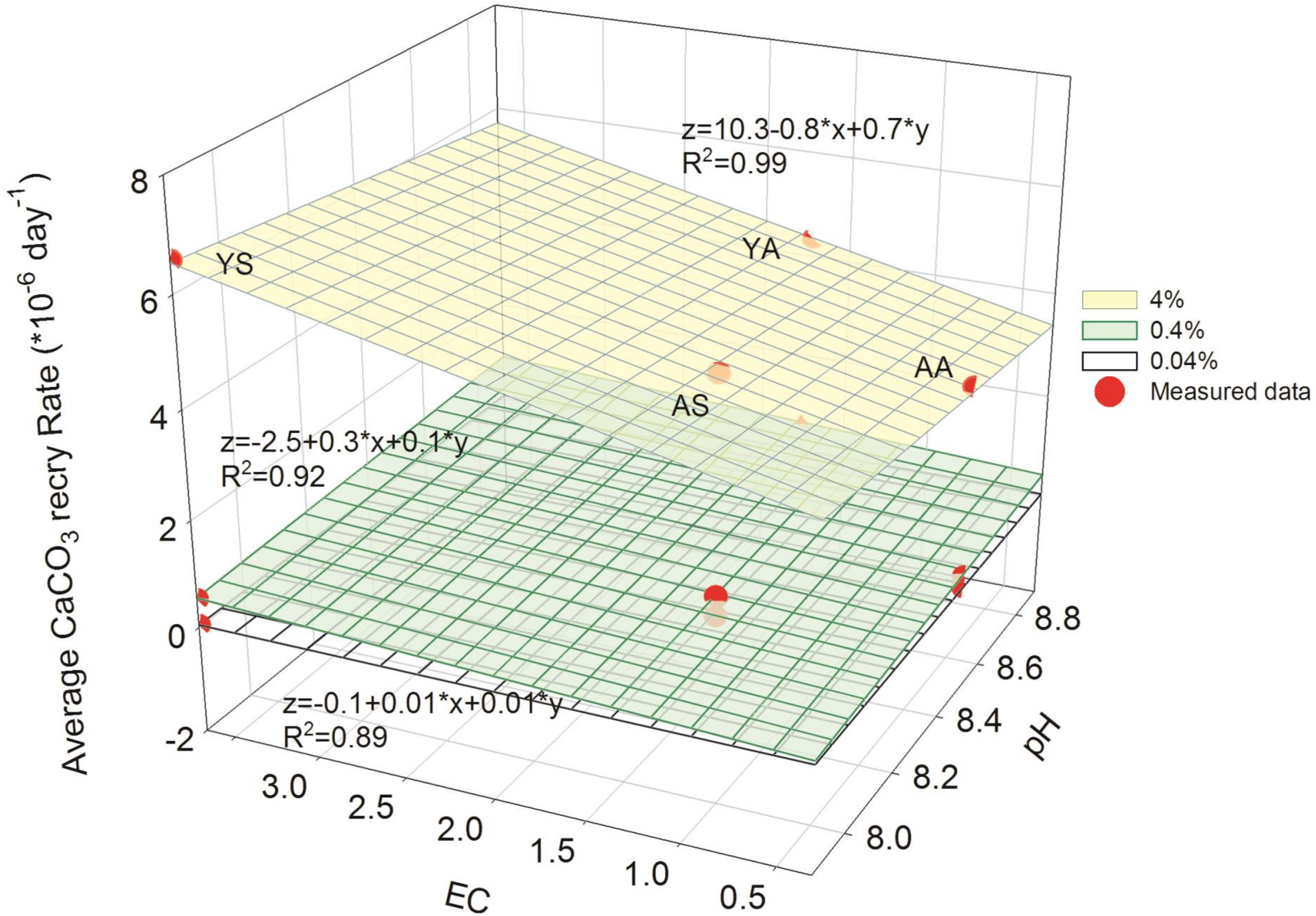
High saline:

	Estimate	p-value
a0	441.637	0.00
a1	-86.186	0.00
a2	-101.850	0.00
a3	6.996	0.00
a4	1.681	0.00
a5	-139.237	0.00
a6	-86.411	0.00

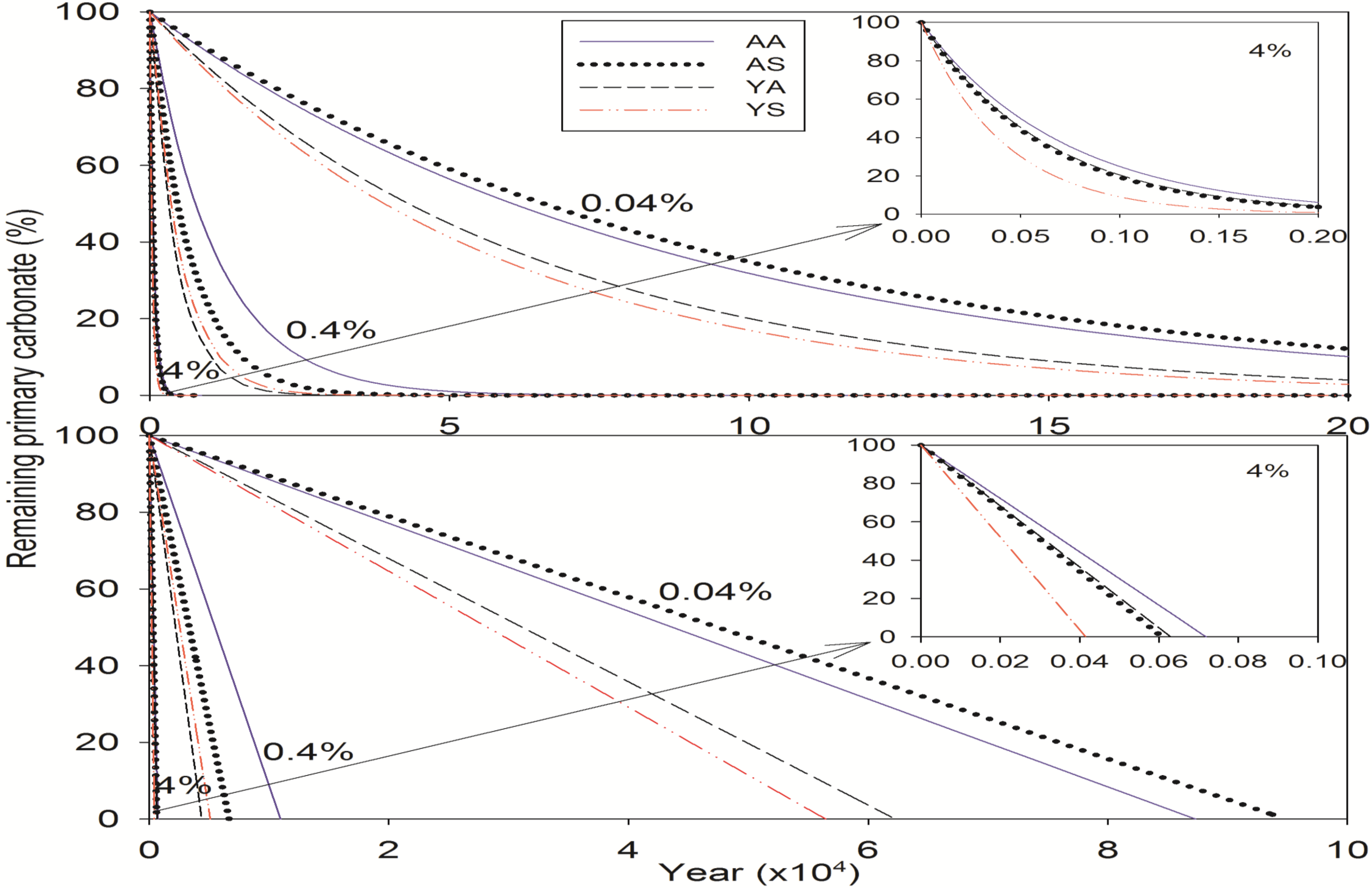
Fig. 7 The relationship between the soil water content and the matric suction and soil texture in different saline soils. pF1: pF matric, pF2: pF osmetic, C_{org} : (g/kg), N_{tot} : (g/kg)

4. Discussion

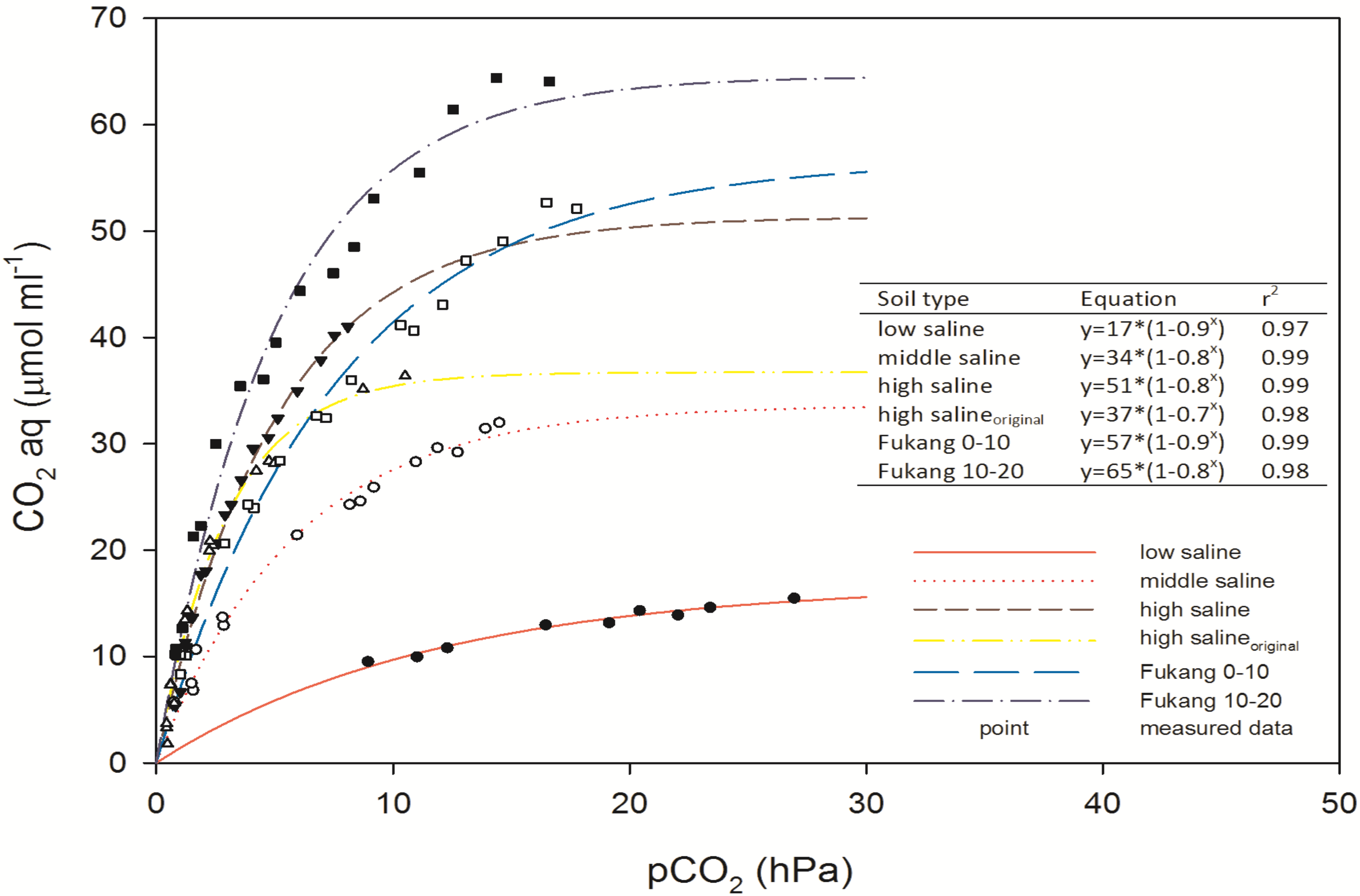
4.1 pH and EC effect on $CaCO_3$ recrystallization



4.2 Geo-chronological reconstruction



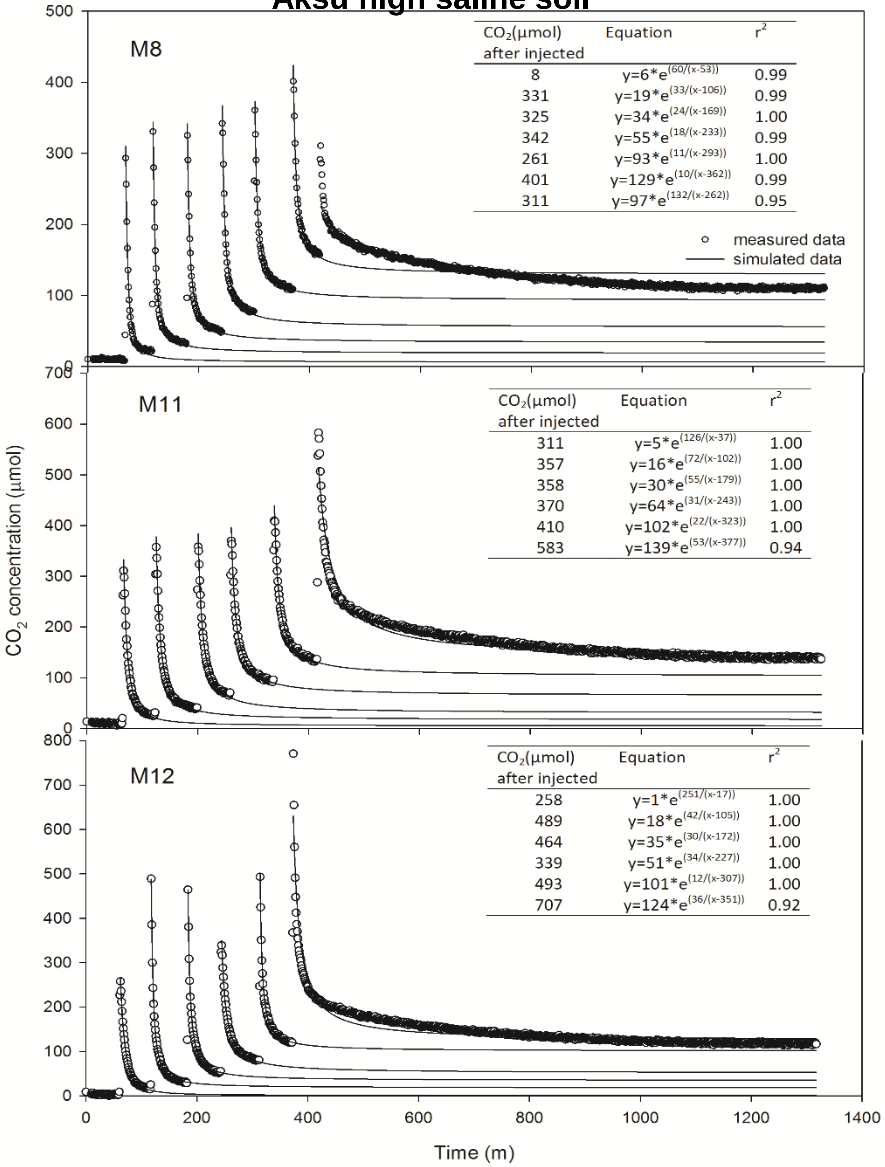
4.3 PH and EC effect on the CO_2 absorption in soil water



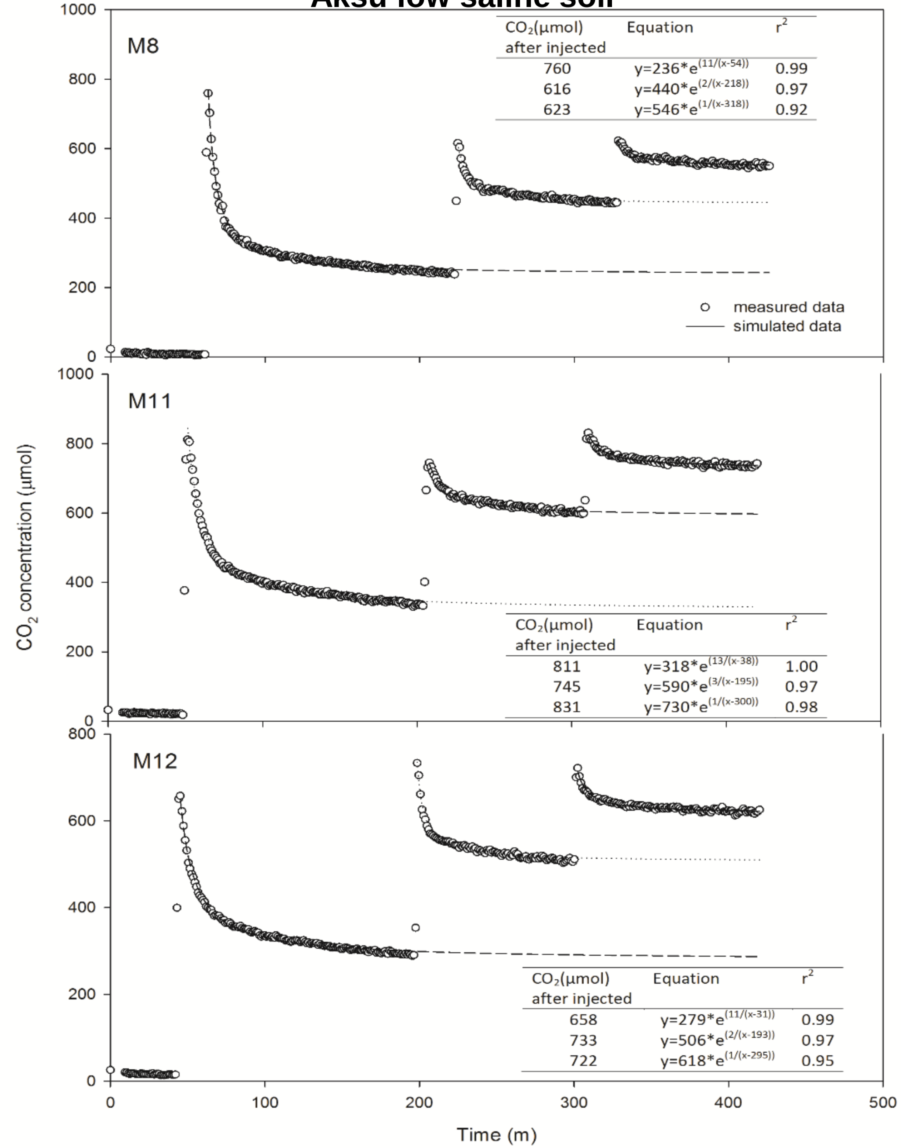
Soil type	Equation	r^2
low saline	$y=17*(1-0.9^x)$	0.97
middle saline	$y=34*(1-0.8^x)$	0.99
high saline	$y=51*(1-0.8^x)$	0.99
high saline$_{original}$	$y=37*(1-0.7^x)$	0.98
Fukang 0-10	$y=57*(1-0.9^x)$	0.99
Fukang 10-20	$y=65*(1-0.8^x)$	0.98

4.3 CO_2 absorption

Aksu high saline soil



Aksu low saline soil



4. Conclusion

1. **A reasonable soil water content (16-26%), lower suction power (below 3500 kPa) and lower matric suction (below 30 kPa) in low saline soil had higher water use efficiency and higher yield.**

2. **Compared to low saline soils at Aksu, the low saline soil at Korla saved 110 mm irrigation and 103 mm total water to reach 1 t ha^{-1} yield and increased 5 kg ha^{-1} mm^{-1} and 7 kg ha^{-1} mm^{-1} water use efficiency for WUE and IWUE.**

3. **Good soil fertility, soil porosity and loose soil, resulting in low bulk density, affected the matric potential and reduced the salt effect to cotton.**

4. **The water logging problem below 30cm in higher saline soil led to the lowest water use efficiency and yield.**

5. **pH and EC play important roles in $CaCO_3$ recrystallization and CO_2 absorption.**


THANK YOU!