Quantify the spatial distribution of salt-affected land in central and southern Iraq

Reporters

Weicheng Wu, Waleed M. Al-Shafie, Ahmad S. Mhaimeed, Feras Ziadat, Alexander Platonov, Hassan H. Al-Musawi, Abdul Jabbar Khalaf, and Ayad H. Abbas, and Kasim A. Saliem

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Key words: spatial distribution, central and southern Iraq, simulation, salinity maps, vegetation.

This report was written and compiled by:
Weicheng Wu (ICARDA), Waleed M. Al-Shafie (MoA- Iraq), Ahmad S. Mhaimeed (University of Baghdad, MoHE, Iraq), Feras Ziadat (ICARDA), Alexander Platonov (IWMI-Tashkent), Uzbekistan Ayad H. Abbass (MoWR), Iraq

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QUANTIFY THE SPATIAL DISTRIBUTION OF SALT-AFFECTED LAND IN CENTRAL AND SOUTHERN IRAQ

— Validation Report

1. Introduction

Through the previous activities, we developed remote sensing-based local and regional-scales salinity models (A1.3) and produced salinity maps (A1.4 and A2.2). In order to understand whether these models are relevant, and whether the maps produced are reliable and can be provided to the local and central Iraqi governments for referential usage, a validation procedure based on the field data is essential to investigate the reliability and the possible improvement (if necessary) of these models and maps.

The same as salinity modeling and mapping procedure, validation is also a harsh challenge due to the strong spatial variability of salinity and limited accessibility for field measurement. We have to tackle this task in terms of the data availability.

As demonstrated in the Review Report of Components A and 1 (Feb 04, 2013), the salinity maps of Musaib and Dujaila have a rather good accuracy, e.g. 82.57-83.01%. We think hence that these salinity maps at pilot site level have been validated. We focus our validation on the regional scale salinity map of Mesopotamia.

A field sampling campaign, as a complement of the sampling conducted in vegetated areas (e.g. croplands) last year, was undertaken and focused in bareland (bare soil, desert, and locally saline land) in the central and southern Iraq in the month of June, 2013. But only 50% of the designed polygons were sampled due to security problem. In order to have a complete view of the regional salinity map, we have to use both the newly sampling data and those obtained along the regional transects last year for our validation .

2. Approach and Procedure

2.1 Data

1) Data from the validation campaign (June, 2013): 24 samples including 71 EM38 readings and 22 lab salinity measurements.

2) 92 field/lab measured EC samples obtained along the regional transects. Samples below 30 cm of the same soil profile were excluded (Output A1.2).

The locations of all samples used for validation are illustrated in Figure 1.

2.2 Salinity map check and simulation

1) Map checking

The previous regional salinity map of the present state 2010 derived from the multiyear MODIS data of 2009-2012 was checked against the two sets of sample data. We noted that the salinity in bare land, especially, in Basrah is underestimated. Meanwhile, it is slightly overstated in vegetated areas, e.g. croplands. Therefore, certain model adjustment and improvement seem necessary.

It is worthy of mention that there is some problem in EM38 readings obtained from the validation campaign, probably due to the strong flooding in the month of May (2013) in Central and Southern Iraq because of the unusual abnormality in comparison with some points which were previously considered reliable (e.g. the saline land mixed with deserts located in northwest of Nassiriah). The recent flooding event might have changed the surface salt accumulation and influenced EM38 readings. Thus, only lab measured EC is used in the successive validation.

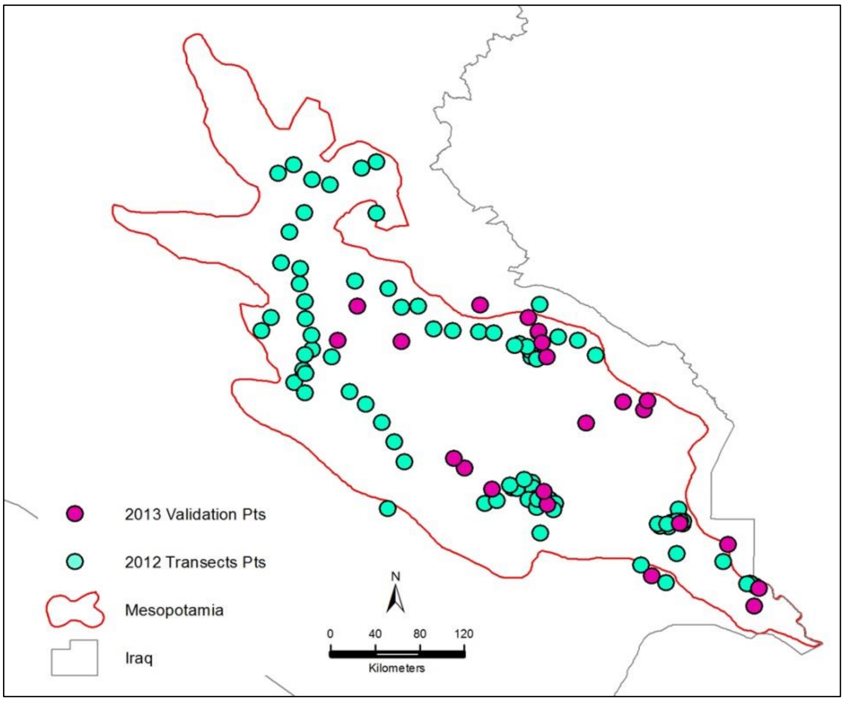

Figure 1: Location of the samples used for validation

2) Regional salinity models

As demonstrated in the output report of A1.3 (Dec. 2012) and review report (Feb. 2013), the regional-scale salinity models are recalled as below:

For vegetated areas:

$$EM_V = 66.338 - 258.114 * \ln(GDVI) \pm 88.882 \text{ (Multiple } R^2 = 0.717) \quad (1)$$

For non-vegetated areas:

$$EM_V = 3055497.34 + 2161.09 * LST - 649347.93 * \ln(LST) \pm 92.524 \text{ (Multiple } R^2 = 0.695) \quad (2)$$

And there is relationship between EC and EMv based on the regional transect samples:

$$EC = 0.0005(EM_V)^2 - 0.0779 EM_V + 12.655 \; (R^2 = 0.8505) \quad (3)$$

3) Model simulation

While producing of the previous regional salinity map of 2010, the RMS error scope in Eq. 1 and 2 was not taken into account. It may be the reason that leads to over- and underestimation in the salinity map. To investigate the error scopes, the GDVI-based model (Eq. 1 and 3) and LST-based model (Eq. 2 and 3) were simulated as shown in Table 1 and Table 2 taking the EMv error, +88.882 for GDVI, and +92.54 for LST as examples. We used the thresholding technique on the multiyear maximum NDVI to define the vegetated and non-vegetated areas. In case of Mesopotamia, when NDVI< = 0.21 or GDVI <= 0.4, it is bareland (fallow has been excluded); otherwise, it is considered vegetated areas. The maximum land surface temperature (LST) during the crop growing period (from Feb.1 to Apr. 14/15. Note: barley harvesting started at the end of Apr.) in Mesopotamia ranges from 305-313 K.

Table 1: Simulation of GDVI-based salinity model for vegetated areas

GDVI	EMv	EC	EMv (+88.88)	EC(+88.88)	Error+
0.40	302.845	34.921	391.727	58.865	11.972
0.45	272.444	28.544	361.326	49.786	10.621
0.50	245.249	23.624	334.131	42.448	9.412
0.55	220.648	19.809	309.530	36.447	8.319
0.60	198.189	16.856	287.071	31.497	7.321
0.65	177.529	14.584	266.411	27.389	6.403
0.70	158.401	12.861	247.283	23.966	5.553
0.75	140.593	11.586	229.475	21.108	4.761
0.80	123.934	10.680	212.816	18.722	4.021
0.85	108.286	10.082	197.168	16.733	3.325
0.90	93.533	9.743	182.415	15.082	2.670
0.95	79.578	9.622	168.460	13.721	2.050

Table 2: Simulation of LST-based salinity model for non-vegetated areas

T	EMV	EC	EMV(+92.54)	EC(+92.54)	Error+
304.00	133.72	11.18	221.14	19.88	8.70
304.50	147.35	12.03	234.55	21.89	9.86
305.00	162.62	13.21	249.72	24.38	11.17
305.50	179.54	14.79	266.63	27.43	12.64
306.00	198.09	16.84	285.28	31.12	14.28
306.50	218.27	19.47	305.67	35.56	16.09
307.00	240.08	22.77	327.78	40.84	18.07
307.50	263.51	26.85	351.62	47.08	20.23
308.00	288.56	31.81	377.17	54.40	22.59
308.50	315.21	37.78	404.43	62.93	25.15
309.00	343.48	44.89	433.40	72.81	27.92
309.50	373.34	53.26	464.07	84.18	30.92
310.00	404.79	63.05	496.43	97.21	34.16
310.50	437.84	74.40	530.49	112.04	37.64
311.00	472.47	87.46	566.22	128.85	41.39
311.50	508.67	102.40	603.64	147.82	45.42
312.00	546.46	119.39	642.73	169.14	49.74
312.50	585.81	138.61	683.48	192.99	54.38
313.00	626.73	160.23	725.90	219.57	59.35
313.50	669.20	184.44	769.98	249.11	64.67
314.00	713.23	211.44	815.71	281.80	70.36
314.50	758.81	241.44	863.08	317.87	76.44
315.00	805.93	274.64	912.09	357.56	82.93

The simulation reveals that with the increase of bareness or reduction of greenness, the error scope also increases. The average EC error extent is 6.37 (with a standard deviation $\sigma = 3.22$) for vegetated areas (GDVI-based) and 36.27 (with $\sigma = 22.81$) for non-vegetated areas (LST-based).

2.3 Reproduction of the present-state salinity map

For vegetated areas, since $\sigma = 3.22$, a simple adjustment, that is, a reduction of 6.37 (the error scope) from the previously produced map derived from the GDVI-based model can largely eliminate the overestimation. However, for non-vegetated areas, a simple addition of 36.17 may not be able to compensate the underestimation due to the strong variability ($\sigma = 22.81$). We have to reproduce the salinity map for the non-vegetated area using Eq. 2 and 3 by taking the error item (-92.54) into account.

For the swamps and its surrounding areas, the salinity predicted is more than 350 dS/m due to the influence of moisture. Obviously such salinity level is not reasonable for swamps and was hence masked out, and replaced by that from vegetated salinity model.

2.4 Validation

The two sets of samples as above-mentioned were combined and imported to ArcGIS in order to compare with their corresponding remote sensing modeled salinity of the newly produced salinity map. 23 samples of 114 are abnormal due to either some problem of sample itself derived from lab analysis (low correlation between Cl^-, Na^+ and EC, $R^2 = 0.047$) or inconsistence between field/lab measured salinity and remote sensing predicted salinity (see Table 3).

Table 3: The abnormal samples and EC couples

OBJECTID	code	Lat	Long	Cl	K	Na	Lab-EC	RS-EC
187	EM12	31.249010	45.913889	0.000	0.000	0.000	3.800	53.609
188	EM13	31.426244	45.694311	0.000	0.000	0.000	1.500	83.291
189	EM14	31.508944	45.604161	0.000	0.000	0.000	6.500	151.270
199	EM25	32.484391	46.319372	0.000	0.000	0.000	20.100	51.645
5	B5	30.449278	47.996694	280.000	110.000	130.260	46.900	4.783
11	B13	30.877139	46.304472	290.000	136.000	204.430	61.200	24.186
12	F6	30.927694	47.336417	520.000	163.000	217.820	81.700	3.373
13	F8	30.967083	47.362222	21.000	1.300	366.500	45.300	3.351
21	H9	32.575278	45.809139	160.000	36.000	109.260	27.500	73.414
37	FP3	30.933139	47.269056	250.000	14.000	19.170	53.500	3.369
38	FP7	30.954972	47.330889	160.000	62.000	152.780	44.800	3.726
110	D7	34.008567	44.981067	665.000	3.240	820.520	127.000	4.748
111	A6 0-30	31.080528	47.419472	66.000	2.920	8929.600	117.900	44.324
112	G1	31.306889	46.233750	24.500	1.790	957.290	106.700	3.456
113	F9 0-30	30.972611	47.379361	8.500	3.100	799.080	83.100	3.320
114	D8	33.861100	44.461667	21.000	0.720	54.690	67.200	4.093
115	FP1 0-30	30.952694	47.252333	310.000	80.000	295.200	58.000	3.578
116	B7	30.449417	47.973278	300.000	71.000	213.300	50.000	4.115
118	H12 0-30	32.571139	46.288194	15.000	2.190	985.390	43.700	4.273
119	K4	32.584333	44.049167	25.000	0.390	87.520	32.700	3.407
120	D12	33.415267	44.277100	100.000	7.220	105.020	27.800	3.695
125	D25	32.392250	46.312306	502.000	1.290	135.140	18.100	7.151
129	G16	31.253278	46.115556	18.500	1.250	112.620	14.600	61.769

However, the remained 91 samples show a good agreement with remote sensing predicted salinity. The observation accuracy is thus 79.8%.

The combined dataset including both field/lab measured and remote sensing predicted salinity was input to SYSTAT for simple regression analysis at a confidence level of 95%. After removing the outliers (23), the statistical accuracy of the new regional salinity map is 80.02% (Figure 2).

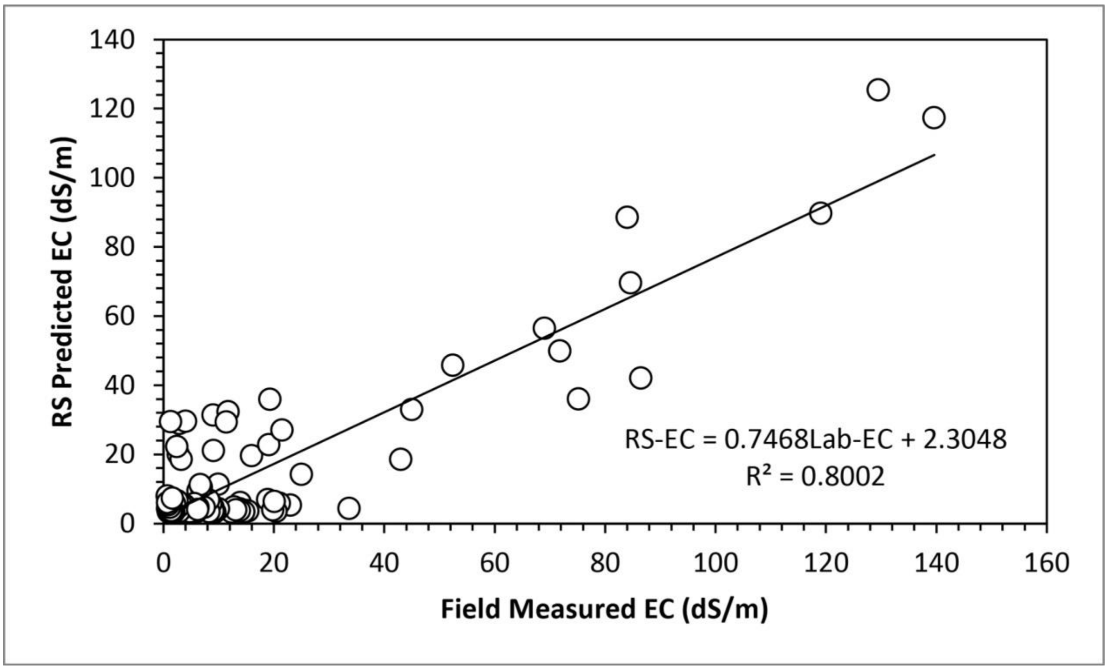

Figure 2: Agreement between the field/lab measured and remote sensing predicted salinity in Mesopotamia

2.5 Validated regional salinity map

Based on the above validation, the newly produced regional salinity map of the present-state (Figure 3) in Step 2.3 is mostly reliable and can be provided to Iraqi local and central governments as reference for future land use planning and agricultural development.

3. Summary

Based on the field investigation and sample analysis, remote sensing provides an operational and reliable tool for salinity mapping and quantification. After this validation, the regional salinity map is considered of high reliability; and the salinity models which were used to produce the map are operational if the error item or extent can be taken into account. However, there are still certain parts, where a number of abnormal points (23) were observed, requiring a further investigation. This will be done when the security condition is improved in Central and Southern Iraq.

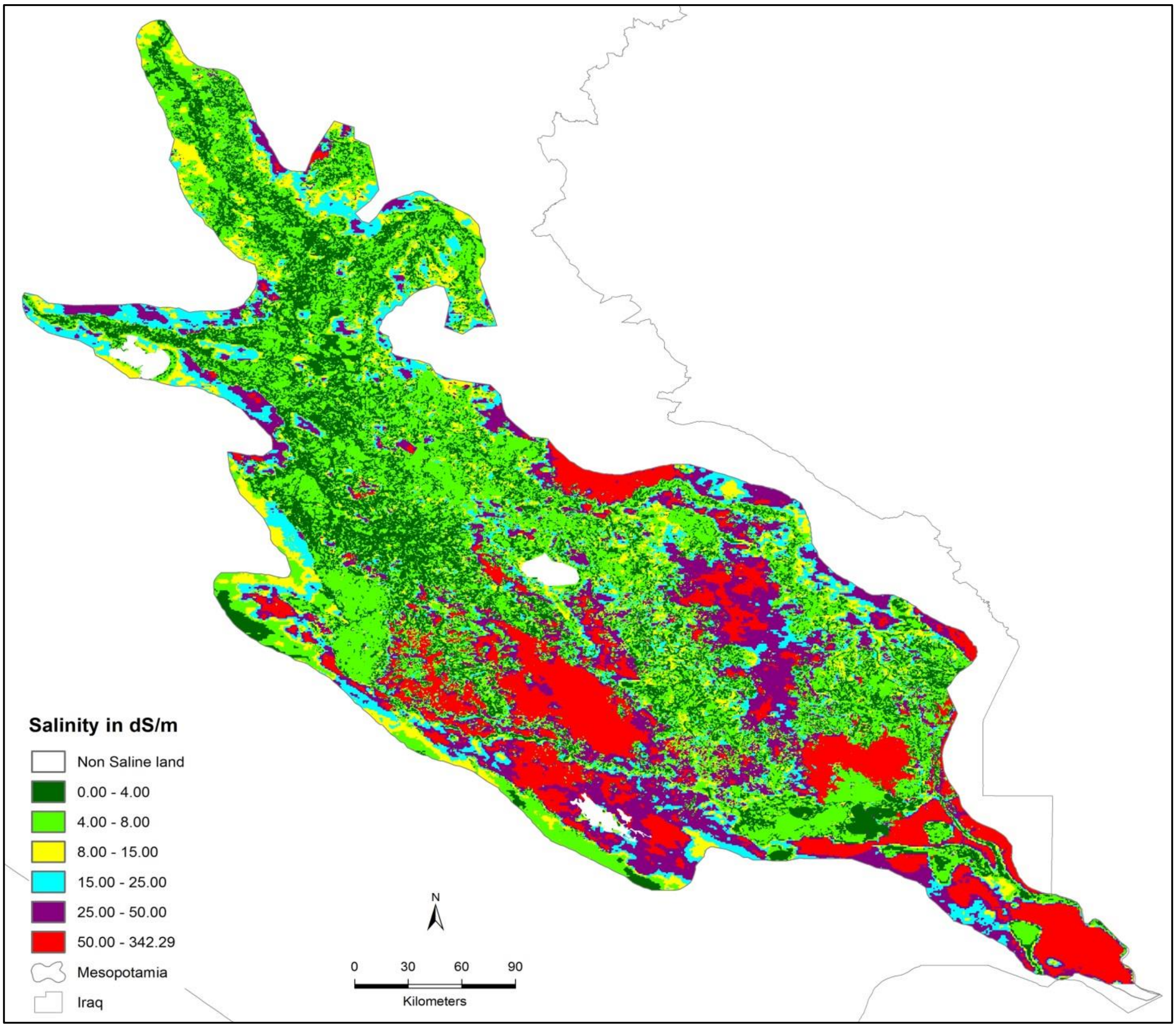

Figure 3: The validated present-state regional salinity map of Mesopotamia

Acknowledgment

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Appendix 1

This is a list of recent and historical data collected by Component A.

Regional data

Data type	**File name**	**Comments**
Meteorological stations	Annual_prc.shp	Only location
Road network	Roads.shp	Whole country
Sampling transects	Transects.shp	
Iraq boundaries	Boundary.shp	Whole country
Governorate boundaries	Governorate.shp	Whole country
Middle south area	Middle_south.shp	
Pilot sites	Pilot_sites.shp	Five pilot sites
Annual precipitation	Annual_prc1	Grid format
Meteorological Data	Meteorological Data.xls	1980-2010
Physiographic regions	Physio.shp	Whole country
Gypsy soils	gypsy_soils.shp	Whole country
Geologic map	Geol.tif	Image file
General soil salinity map	IQ_FAO_salinity_Map1980.png	Image file
General soil map	1957_Exploratory_soil_map_of_Iraq.jpg	Image file
General soil degradation	dg_rate1_lowres.jpg	Image file
Location of cisterns	cistern.shp	Basrah
Location of wells	well.shp	Basrah
Canals distribution	canals.shp	
River stream	river_stream.shp	
Land use	MODIS (folder)	No legend
vegetation	Vegetation (folder)	Each crop type in one shapefile

Abu Flos

Data type	**File name**	**Comments**
Profile location	Profiles_abfloos.shp	Profiles location
Profile description	AboFloos_Description_Profiles.docx	Profiles description
Profile analysis	Abu Flos soil analysis 2000.xls	Profiles analysis
Soil Permeability	Soil Permeability Abu flos 2000.xlsx	
Surface & Ground Water quality	Surface & Ground Water Analysis Abu Flos 2000.xlsx	
Soil salinity map	Salinity_abofloos.shp	Historical map
Soil map	Soil_abofloos	Legend not identified

Dujailah

Data type	**File name**	**Comments**
Soil salinity map	Salinity_Dijaila_Date_1950s.shp	Salinity in 1950s
Auger holes location	Auger hole_XY_Dujailah.xlsx	Only coordinates
EM38 data	Dijaila EM38.xlsx	Location, EmV, EmH
EM38 data, plots	Dijaila_EM38_Sites_XY.xlsx	Location, EmV, EmH
Morphological description	Morphological description.doc	
Profile description	Profiles.doc	
Soil analysis	Soil Analysis & X_Y_Dijaila.xlsx	
Soil analysis	Soil Analysis for Dijaila.xlsx	
Pedon description and climate	Soil Test Dujailah 2011.xlsx	
Canals distribution	canals.shp	

Musaib

Data type	File name	Comments
Soil salinity map	Salinity_Mussaib_Date_1990s.shp	Salinity in 1990s
Soil profiles	Soil Data1994.xlsx	Soil data 1994
Soil profile location - UTM	profile locationUTM.docx	1994
Location of bore holes	Auger_hole.shp	
Location of profiles	Profile_site.shp	
Location of soil samples	Surface_sample.shp	
Ditch information	Ditchl.shp	Length, characteristics
Distribution of irrigation canals	Irrigtion_Canals.shp	No water quality data
Soil map	Soil_map.shp	1994
Soil profile data 2011	Soil_R_S_2011_Musaib_DATA.xls	
AccuPAR readings	AcuPAR_readings.xlsx	

Shat El Arab

Data type	File name	Comments
Soil salinity map	SAA_Salinity_Map_F.shp	Historical data
Soil map	SAA_Soil_Map_F.shp	Historical data

West Gharaf

Data type	File name	Comments
Soil map	Soil_units.shp	Historical
Soil salinity map	Export_SOIL.shp	Historical
Soil data (mapping units)	Gharaf Soil data13Feb.xls	Historical
Location of soil profiles	Profile_location.shp	Historical
Profiles description	Hard copy for typical pedons	Available upon request