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Climate Change, Land Degradation and Food Security in Iraq –
An Integrated Assessment Using Space Technology

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ICARDA

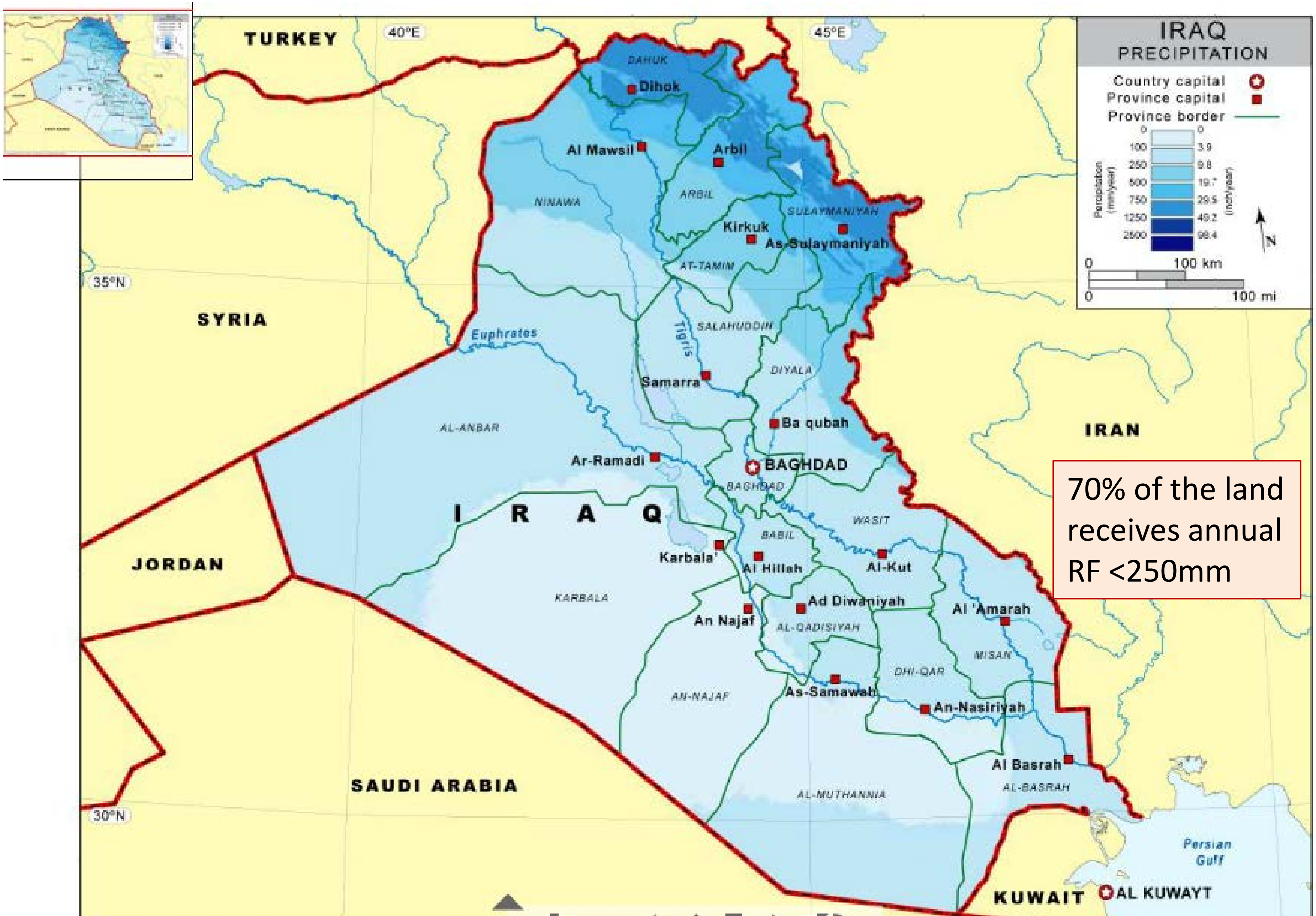
CGIAR

1.Background: Problems

Why do we need such research?

- Climate change, leading to unfavourable impacts on water resources (T ↑ and P↓) which would further lead to decline of crop production;
- Land degradation, especially, salinization, the common problem in dryland environment, has caused reduction of land productivity and cropland abandonment and hence reduction in crop yield;
- Harsh challenge in food security in future in dryland countries and regions.

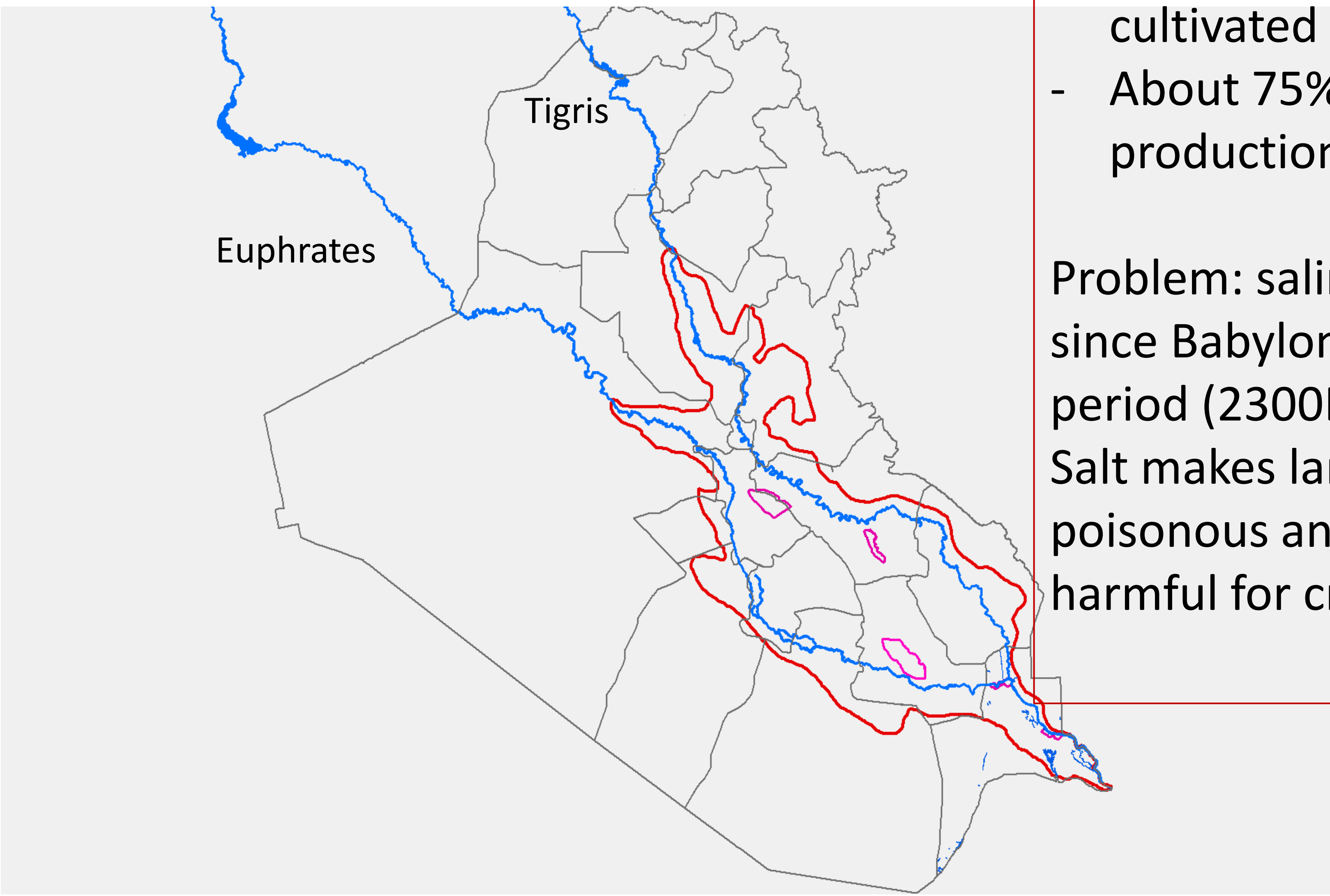
Case study: Mesopotamia, Iraq



70% of the land receives annual RF <250mm

Precipitation Map of Iraq (http://www.fao.org/ag/AGP/AGPC/doc/Counprof/Iraq/Iraq.html)

Mesopotamia



Known as the land between two rivers:

- 75% of the total cultivated land
- About 75% of crop production

Problem: salinization since Babylonian period (2300BC)
Salt makes land poisonous and harmful for crops.

Climate change

IPCC (2007) projected climate change in Western Asia including Iraq in 2080/90 in comparison with that of 1980/1990:

- T increase by 2°C with high probability of 0.99

- P decrease by 0.1mm/day

This means water resources ↓ and Evaporation ↑, rainfed agriculture will become no longer possible in some areas. Crop production and food security will be faced with challenge.

Objectives

- To investigate impacts of land degradation, in particular, salinization in space and time;
- To understand the impacts of climate change with higher resolution datasets;
- To conduct an integrated assessment on food security by space technology.

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2. Method and Results

2.1 Multiscale and multitemporal salinity mapping by remote sensing

1) Field sampling (EM38 measurement, soil sampling, AccuPAR reading) in Mesopotamia

Sites	Soil Profile (0-100cm)	Surface Soil Samples (0-30cm)		EM38		AccuPAR
		Jul 2011-Apr 2012	Supplemental Jun-Jul 2012	Mar-Apr 2012	Supplemental Jun-Jul 2012	Mar-Apr 2012
Musaib	13	30	6	45	23	36
Dujaila	5	17	6	65	17	17
West Garraf(Italian)		22	4	57	17	15
Shat-Al-Arab	4	16		54		36
Abu Khaseeb	5			15		15
Transects						
Transect 1		20		60		60
Transect 2		44		132		25
Total	27	165		485		204

2) Satellite image processing (Landsat ETM+, RapidEye and SPOT) including atmospheric correction using FLAASH model
3) Multispectral transformation to derive different **vegetation indices** such as NDVI, EVI, SARVI, SAVI; and **non-vegetation indices** such as NDII, PC1, 2, Tasseled Cap Brightness, and spring Surface Temperature (ST, only for Landsat ETM+).

We introduced a new vegetation index, GDVI -- Generalized Difference Vegetation Index, developed by Wu (2012) for this study.

Why GDVI?

The mechanism behind is that through power, the vegetation information in near infrared band gets more amplified in comparison with red band. For low vegetation cover, especially, dryland, GDVI is more sensitive than any other vegetation index.

$$GDVI = \frac{\rho_{NIR}^{n} - \rho_{R}^{n}}{\rho_{NIR}^{n} + \rho_{R}^{n}}$$

where ρ_{NIR} and ρ_{R} are respectively reflectance of the near infrared (NIR) and red (R) bands, and *n* is power number. The dynamic range of GDVI is the same as NDVI from -1 to 1; and when *n* = 1, GDVI = NDVI.

When *n* = 2, GDVI^2 = $\frac{\rho_{NIR}^{2} - \rho_{R}^{2}}{\rho_{NIR}^{2} + \rho_{R}^{2}}$

When *n* = 3, GDVI^3 = $\frac{\rho_{NIR}^{3} - \rho_{R}^{3}}{\rho_{NIR}^{3} + \rho_{R}^{3}}$

When *n* = 4, GDVI^4 = $\frac{\rho_{NIR}^{4} - \rho_{R}^{4}}{\rho_{NIR}^{4} + \rho_{R}^{4}}$

Presented in the 8^{th} International Soil Sciences Congress (8^{th} ISSC, May 15-17, 2012, Izmir, Turkey) and selected for publication with STII (Soil & Tillage Research)

4) Derivation of the maximum multiyear VIs and Non-VIs for the period e.g., 2009-2012 (this is only applicable for Landsat imagery)

Why do we need this procedure?

- **To fill the gaps of Landsat ETM+ imagery and**
- **To avoid crop rotation and fallow (previous studies did not consider this**)

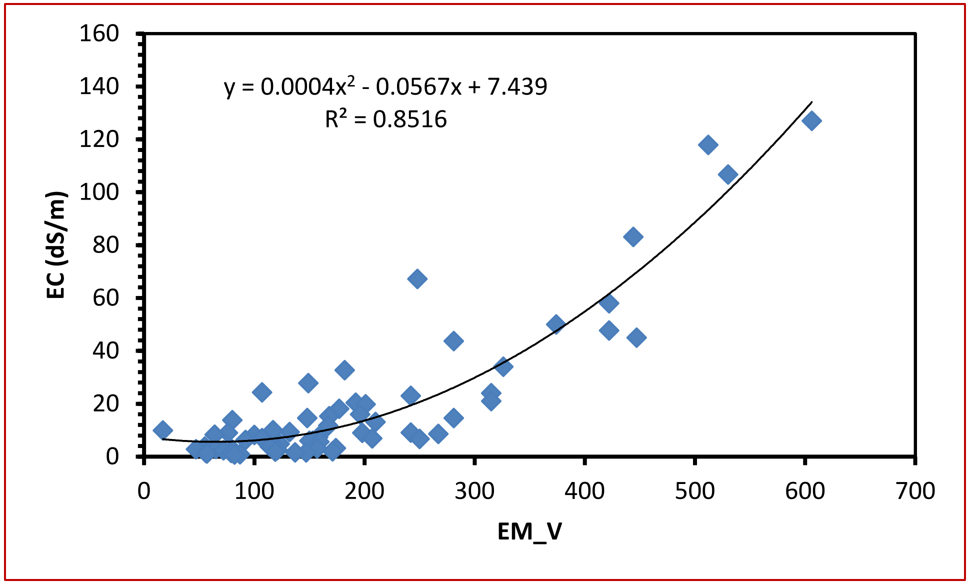
5) Salinity models development for pilot sites by coupling remote sensing indicators with field measurements by linear least-square regression analysis

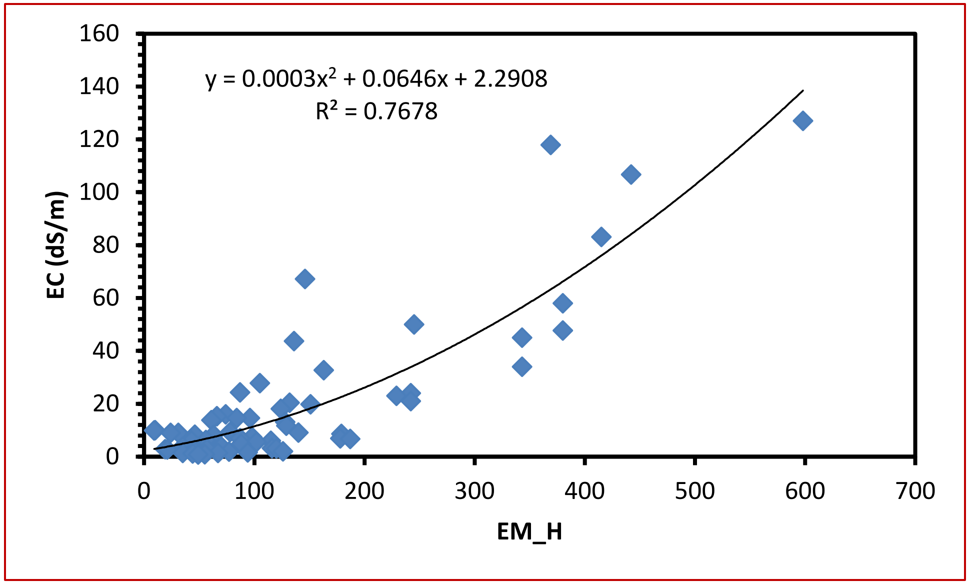
Salinity models developed from pilot sites: Musaib

Vegetated Area	Multiple R^2
$EM\_V = -824.134 + 918.536GDVI - 754.204\ln(GDVI) \pm 41.7$	**0.925**
$EM\_H = -606.197 - 460.043\ln(GDVI) + 245.086\exp(GDVI) \pm 48.559$	0.862

Non-Vegetated Area	Multiple R^2
$EM\_V = 2570683.24 + 1821.24ST - 546476.07\ln(ST) \pm 62.944$	0.829
$EM\_H = 2608853.46 + 1842.4ST - 554286.69\ln(ST) \pm 51.217$	**0.846**

Note: EM_V and EM_H – are respectively vertical and horizontal readings of EM38; ST – multiyear maximum spring surface temperature in K; GDVI – Generalized Difference Vegetation Index

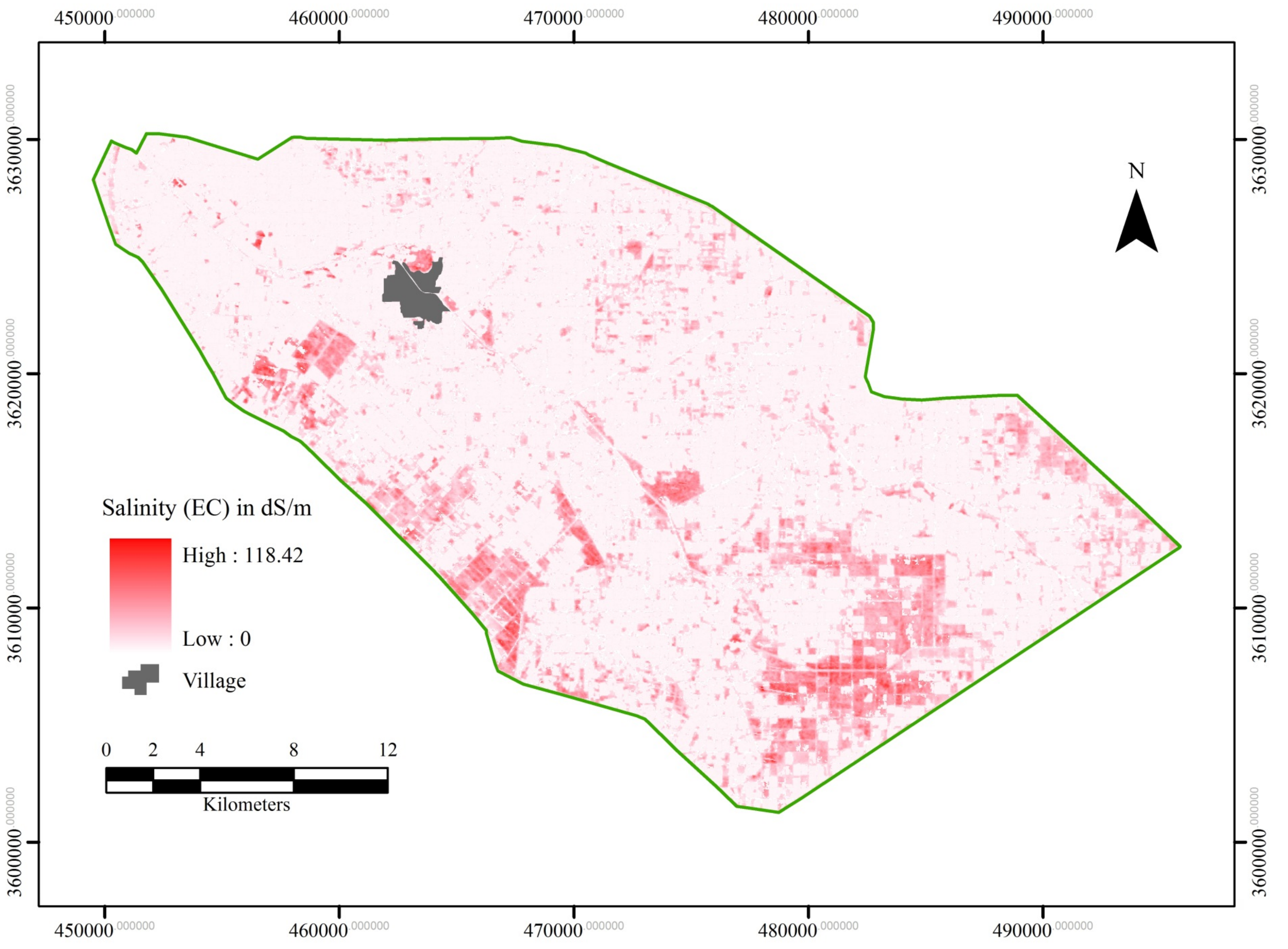


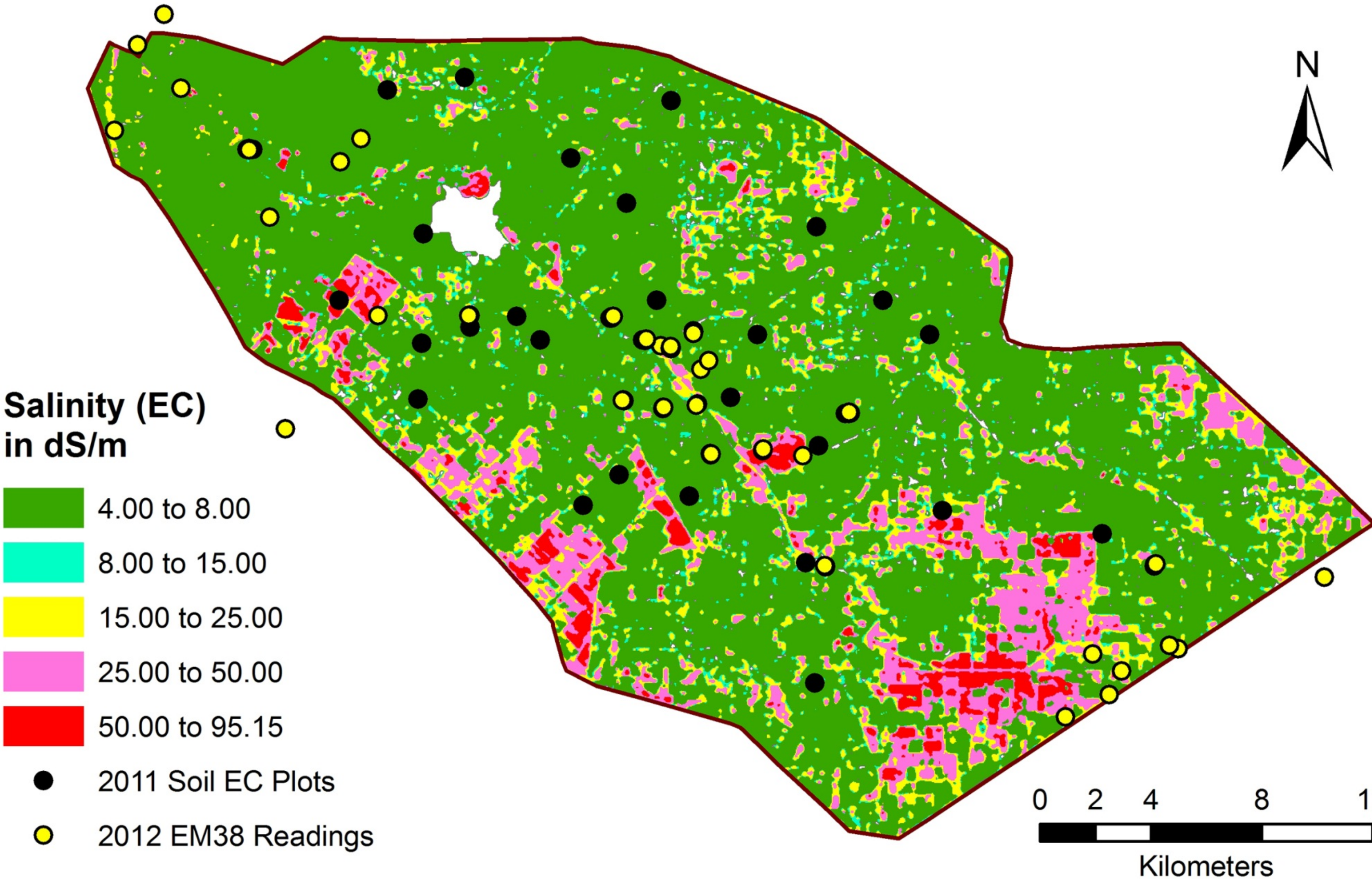


Relationships between EM 38 readings and soil lab EC

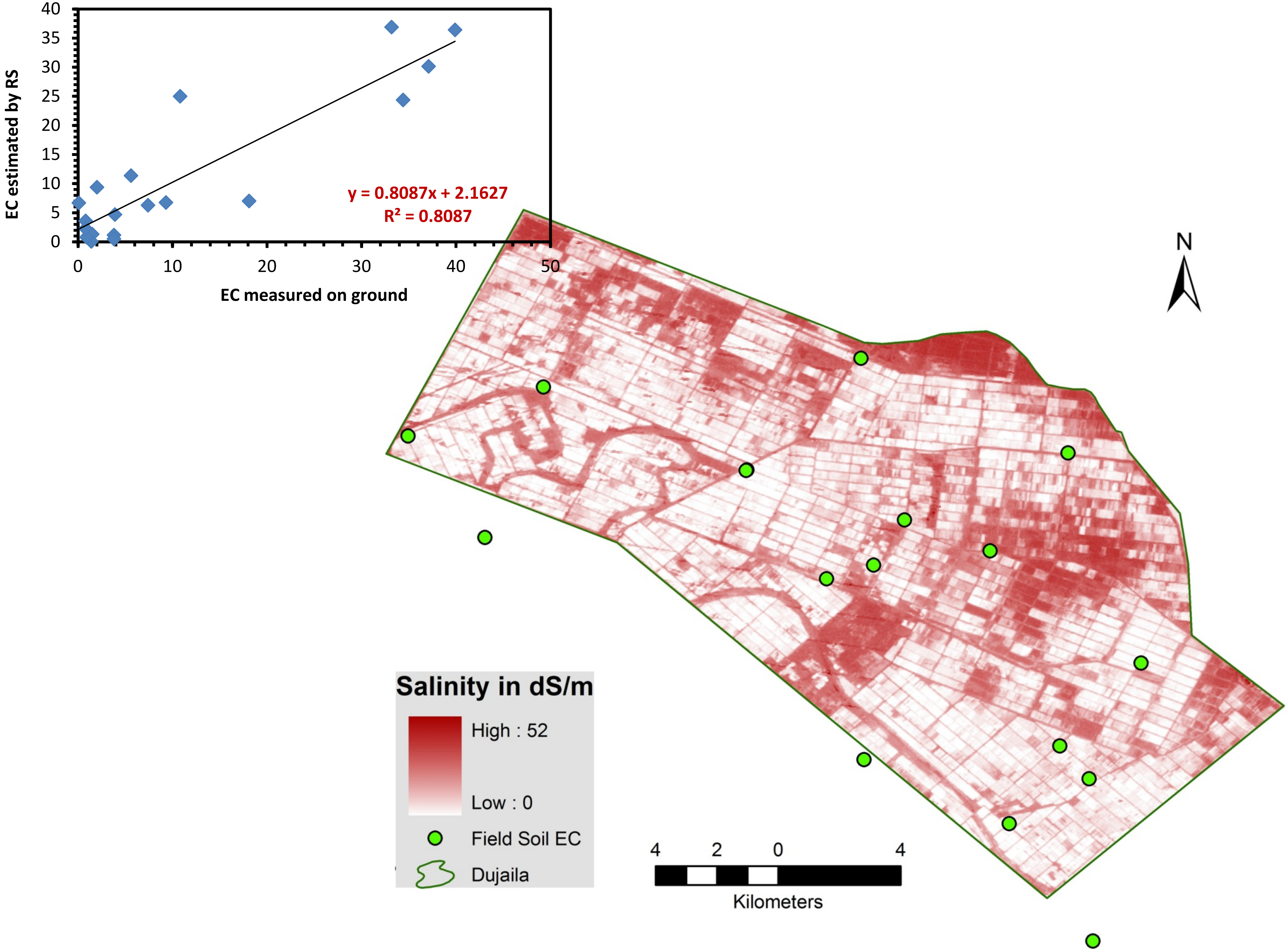
based on field measurement and lab analysis in the Mesopotamian Region

Salinity maps of pilot sites





Verification Accuracy : R^2 = 0.811



EC estimated by RS
EC measured on ground
0
5
10
15
20
25
30
35
40
0
10
20
30
40
50
y = 0.8087x + 2.1627
R² = 0.8087
N
Salinity in dS/m
High : 52
Low : 0
Field Soil EC
Dujaila
4
2
0
4
Kilometers

Regional salinity models

For vegetated areas:

EM_V = 66.338 -258.114*ln(GDVI) ± 88.882

(multiple R^2 = 0.717)

Non-Vegetated areas:

EM_V = 2874415.66+2.035.443*ST-610991.724*ln(ST) ± 97.653

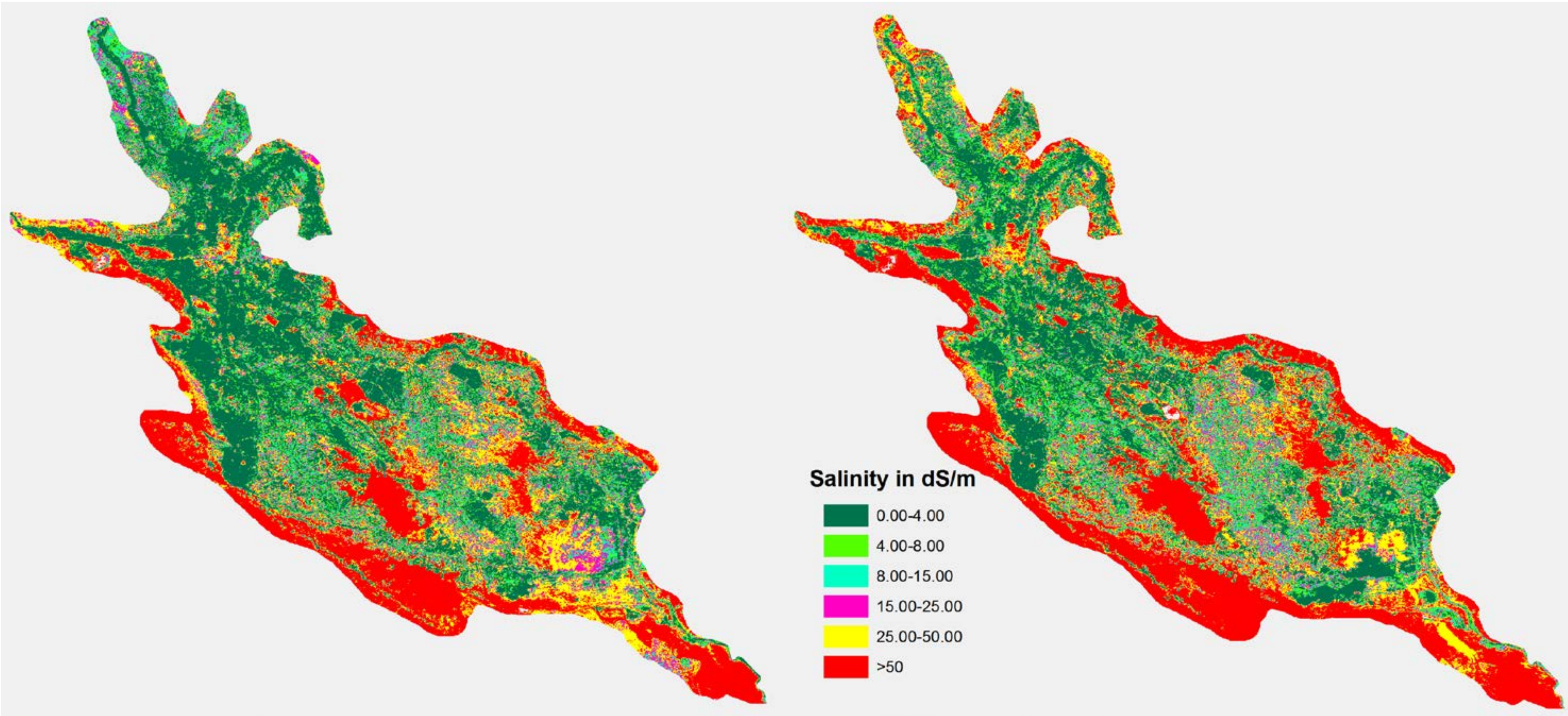
(multiple R^2 = 0.662)

Upscaling test

Models developed from high resolution data such as Landsat, RapidEye and SPOT needs a upscaling test, that is to say, to check whether these models are applicable to MODIS data.

Result reveals the these models are applicable (R^2= 0.88).

Regional salinity maps

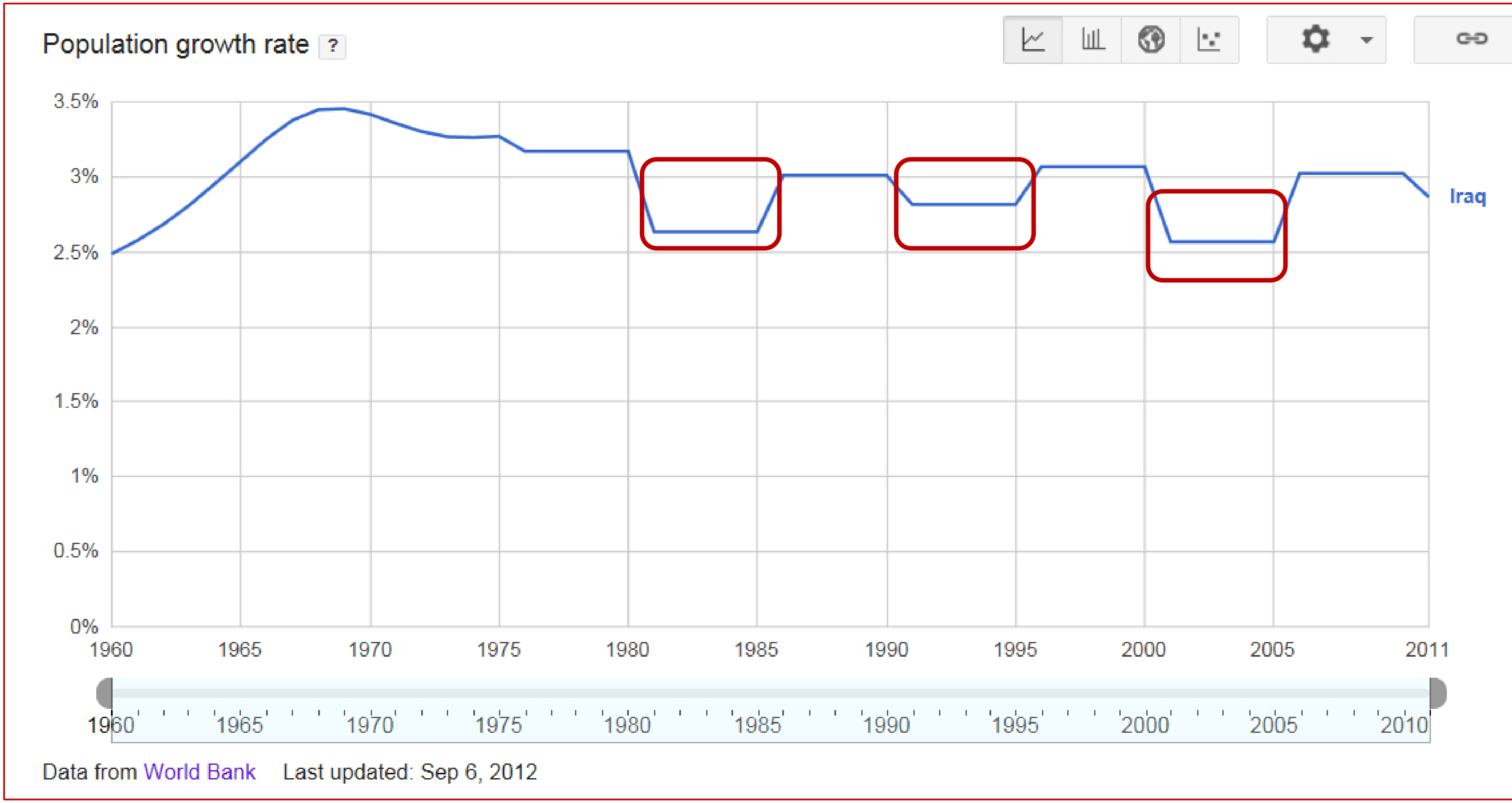


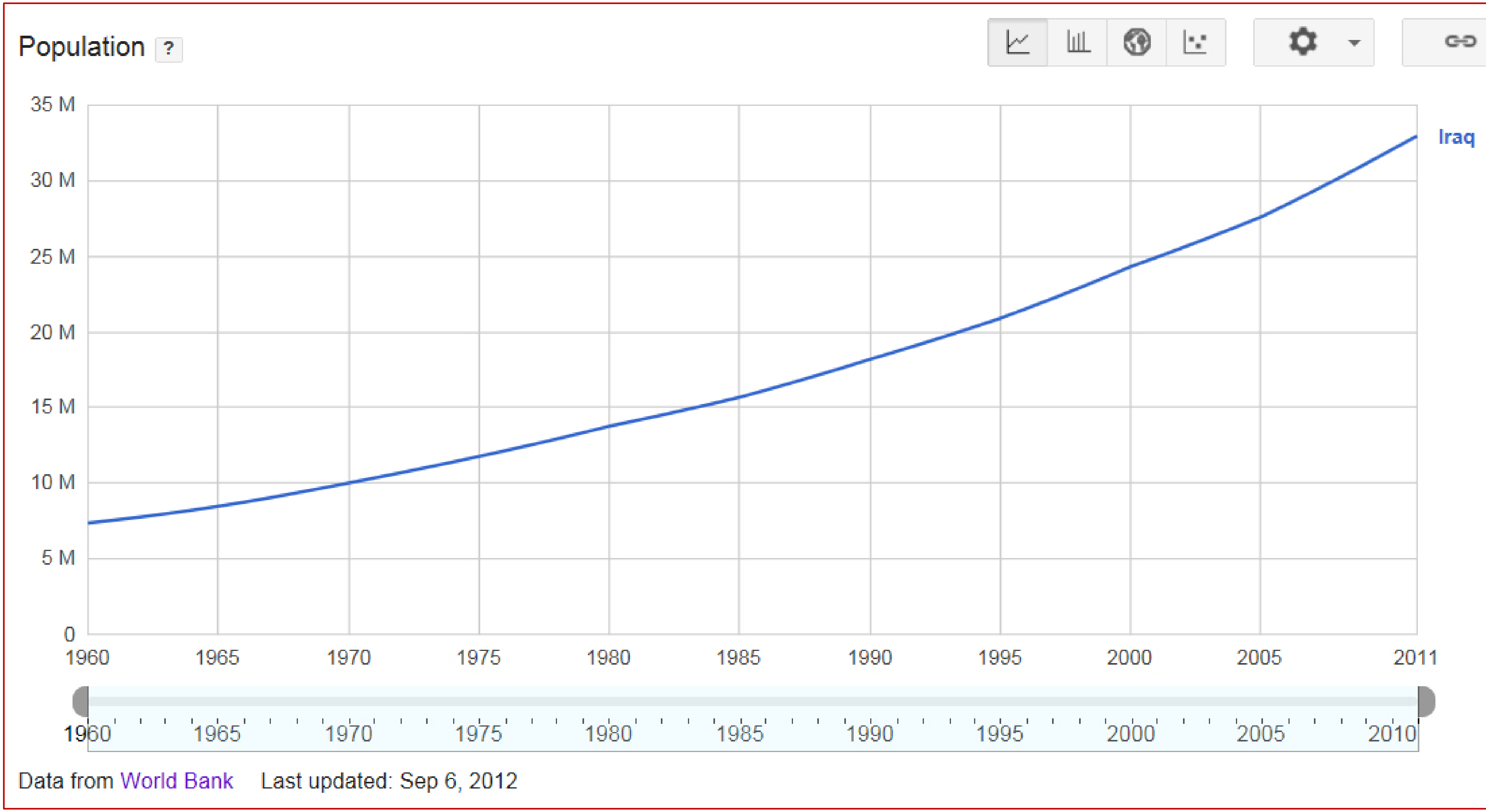
2000-2002

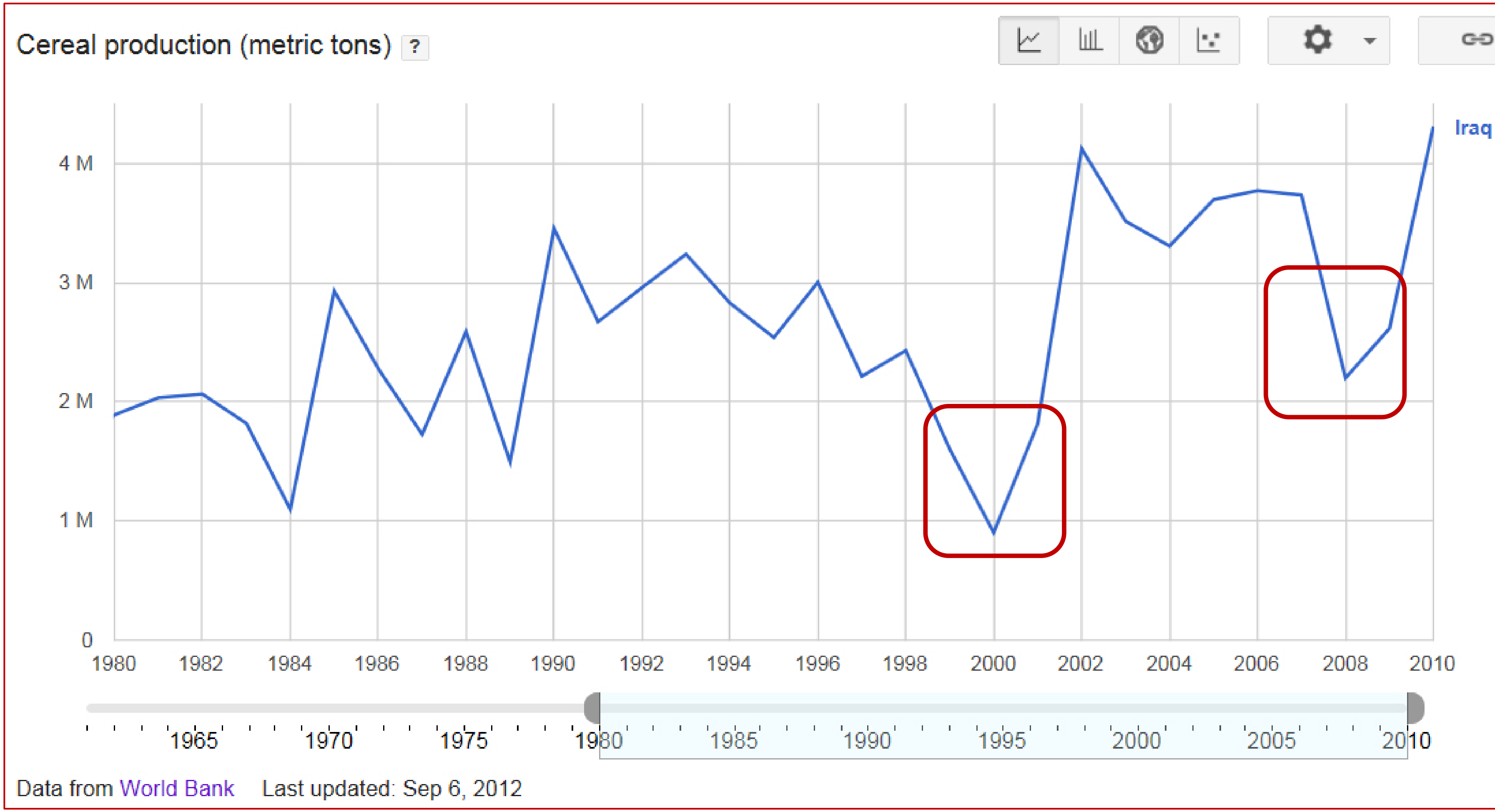
2009-2011

Strongly salinized area (EC >15 dS/m) has increased at a rate of 804km^2/yr!!!

2.2 Population growth and crop production

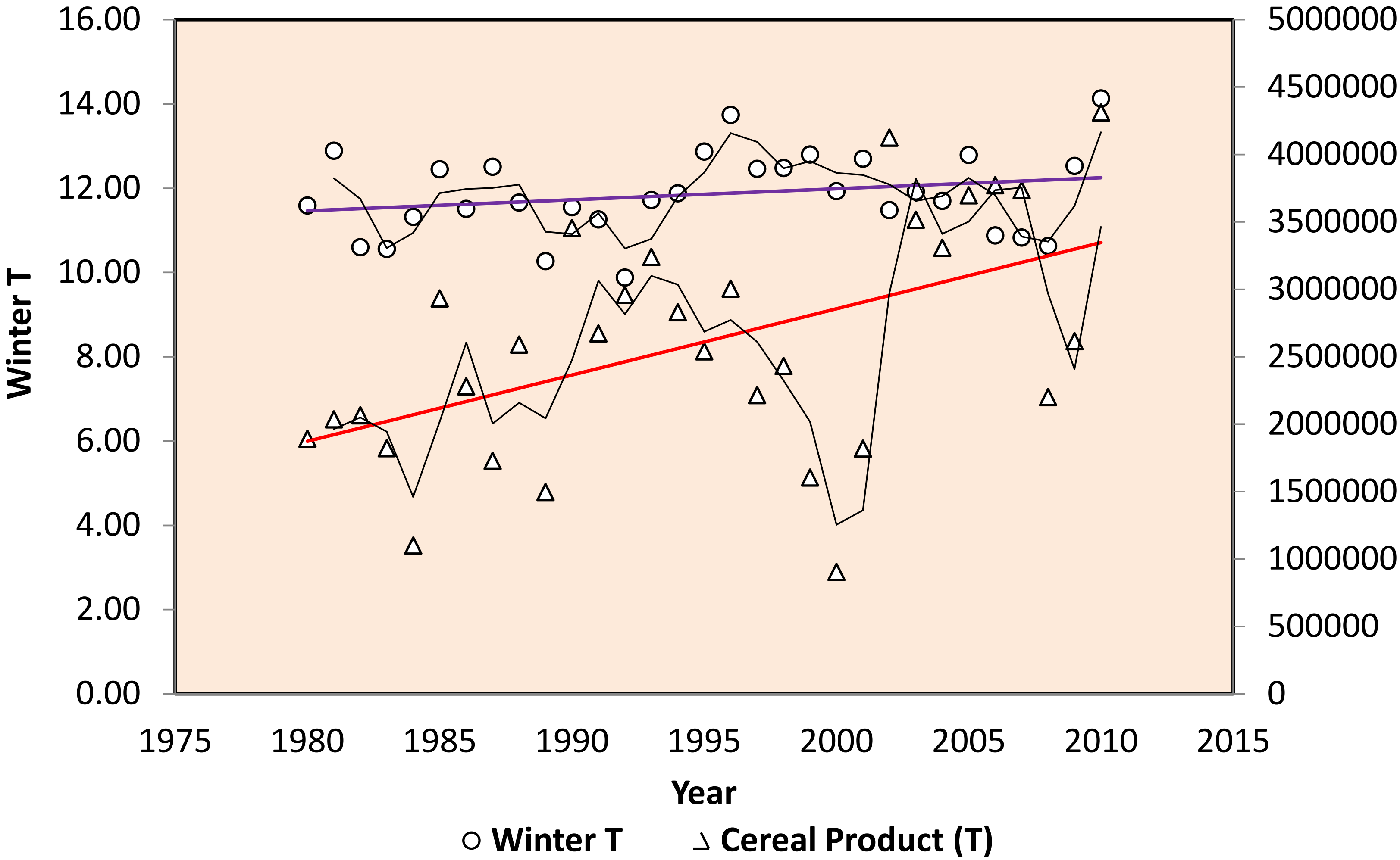



Population ?
35 M
30 M
25 M
20 M
15 M
10 M
5 M
0
1960
1965
1970
1975
1980
1985
1990
1995
2000
2005
2011
Iraq
2010
Data from World Bank
Last updated: Sep 6, 2012



Cereal production (metric tons)
?
Iraq
4 M
3 M
2 M
1 M
0
1980
1982
1984
1986
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
1965
1970
1975
1980
1985
1990
1995
2000
2005
2010
Data from World Bank
Last updated: Sep 6, 2012

2.3 Winter T change and its influence on cereal production



3. Food Security

Although more field validation is necessary, cropland decrease due to extending salinity, winter T increase leading to reduction of cereal production (insects can not be killed due to warm winter), and on the contrary, population grows steadily in the country requiring more food supply. Hence, food security is becoming a harsh challenge (the shortage simulation is to be completed in the following months).

4. Summary

Despite this study is still on going (not yet complete), this case study demonstrates the usefulness and power of space technology in assessing land degradation, climate change, and their impacts on food security in dryland countries or regions.

Thank you for your attention!