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UEA Water Security

DEV INTERNATIONAL DEVELOPMENT University of East Anglia

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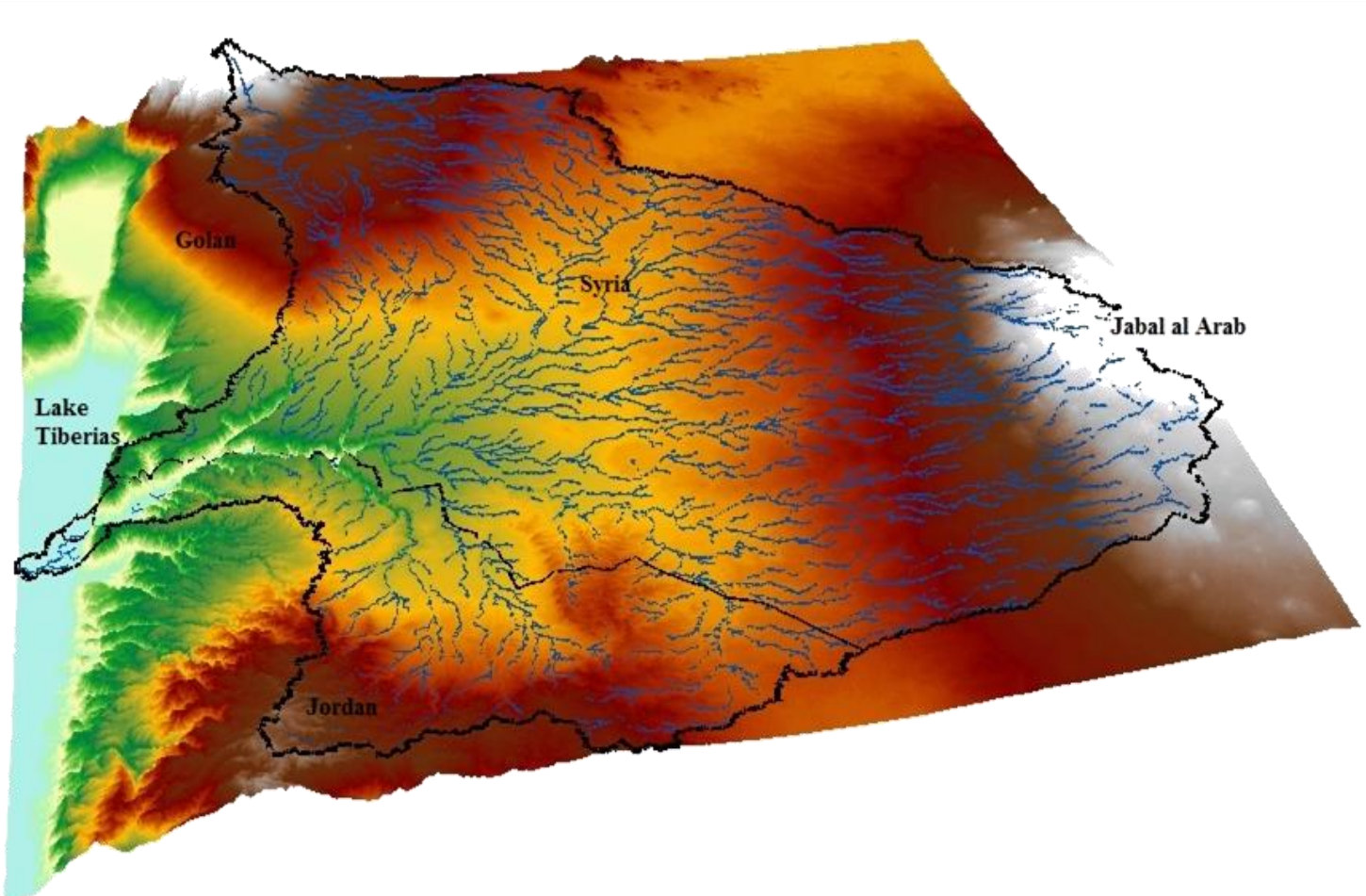
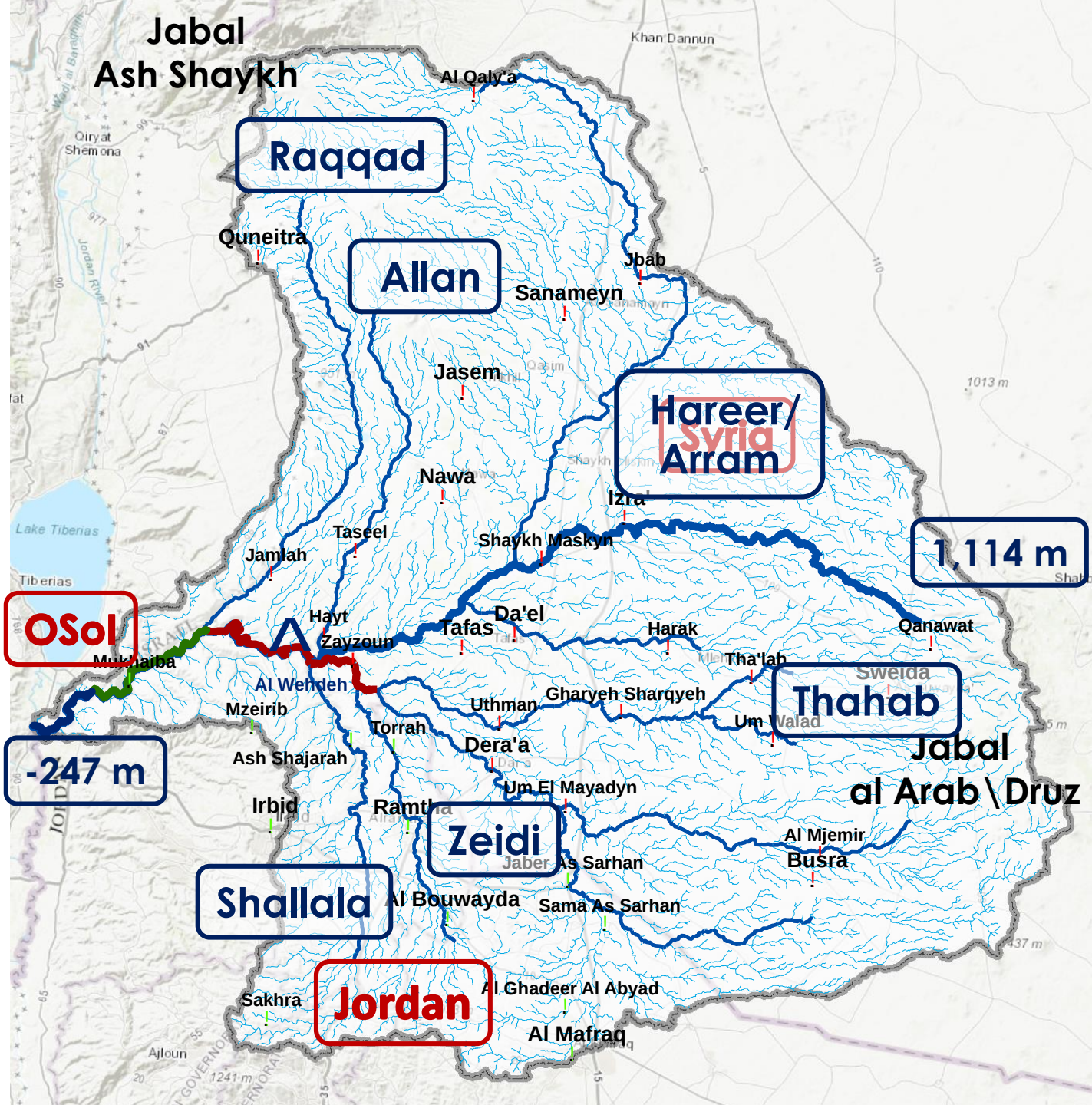
Diplomacy on the Yarmouk, the Jordan River's forgotten tributary

Insight from satellite imagery into Yarmouk groundwater and rivers



Yarmouk River

- Largest tributary of the Jordan river
- Area: 7,387 Km^2
- Strahler 7th order
- Length of Main Tributary from Highest to Lowest: 144Km
- Main tributaries: Raqqad, Allan, Hareer/Arram, Thahab, Zeidi, Shallala
- 3 countries: Syria (80%), Jordan (19.7%), Occupying State of Israel-OSol (0.3%)
- Borders:
- **Syria/Jordan: 31.2 Km**
- **Jordan/Golan: 19.4 Km**
- **Jordan/OSol: 11.1 Km**



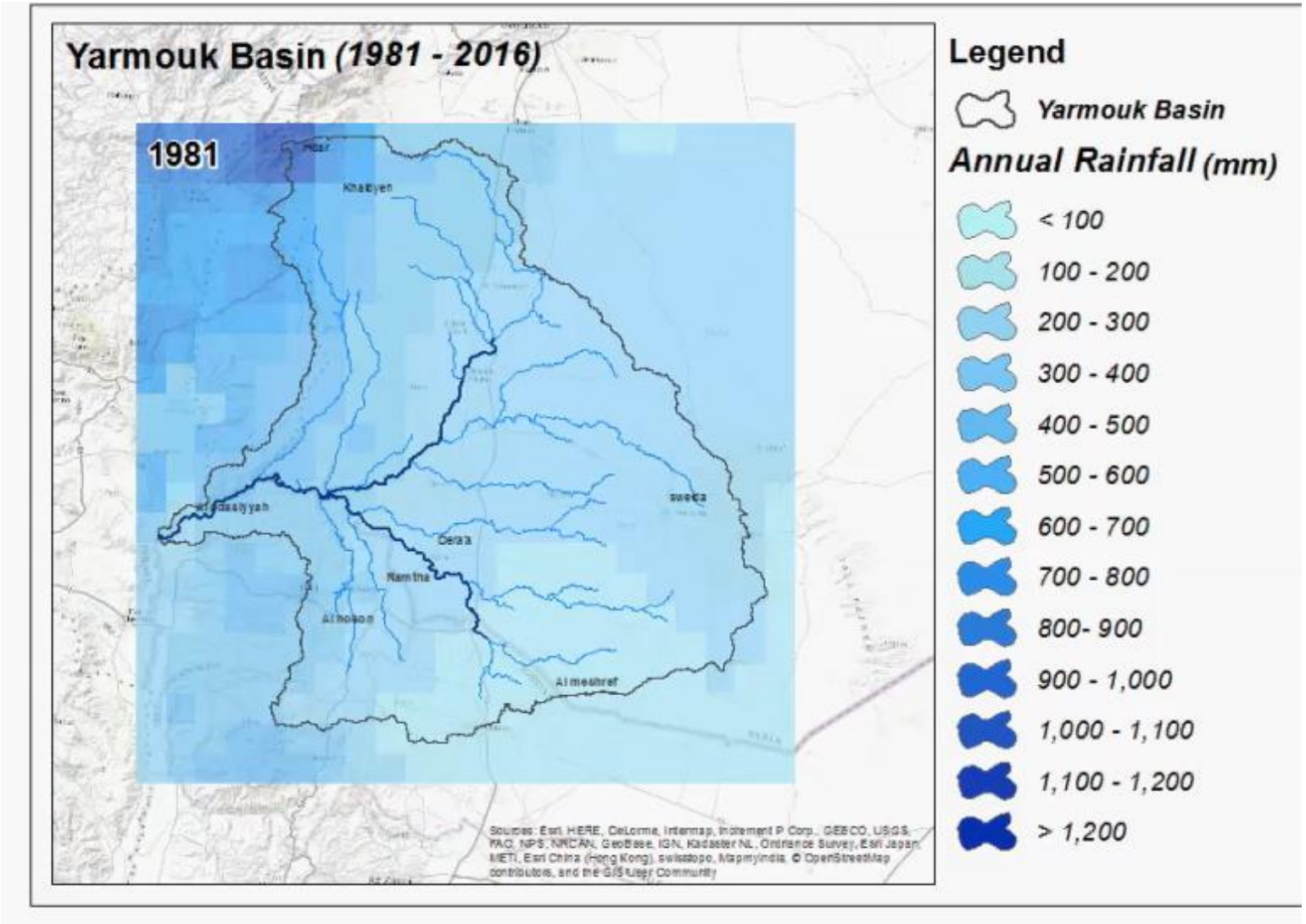
Documentation collated and datasets

- > 200 references: books, peer-reviewed articles, reports, thesis, maps, official websites, personal communications
- From 1889 (Schumacher et al. "*Across Jordan, an exploration and survey of part of Hauran and Jaulan*") to 2017
- 9 different platforms satellites datasets (CORONA, SPOT 5, GeoEYE, Landsat (5-8), MODIS, Active\Passive Radar

Difficulties and challenges

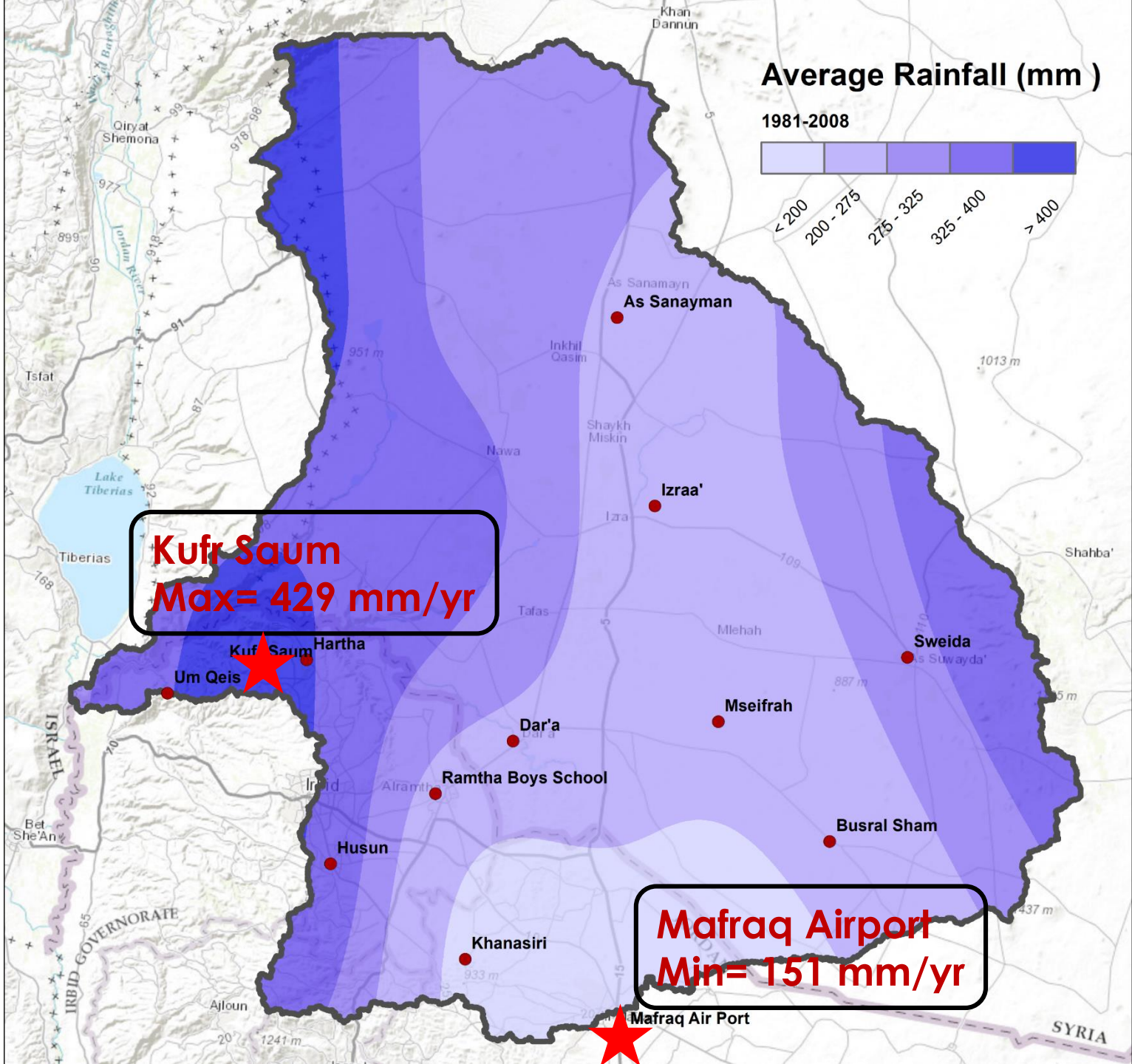
- Contradiction
  - Area of the watershed (ranges from 6,700 Km2 to 8,378 Km2)
  - Length of the river (varies from 40 Km to 143 Km)
  - Flow data (variable, not always clear)
- Major Gaps
  - Long-term accurate precipitation
  - Flow gauging stations
  - Springs discharge
  - Wells extraction
  - Dams actual retention
  - Detailed LUC

Rainfall Amount (MCM)
CHIRPS – 5Km (1981 – 2008)



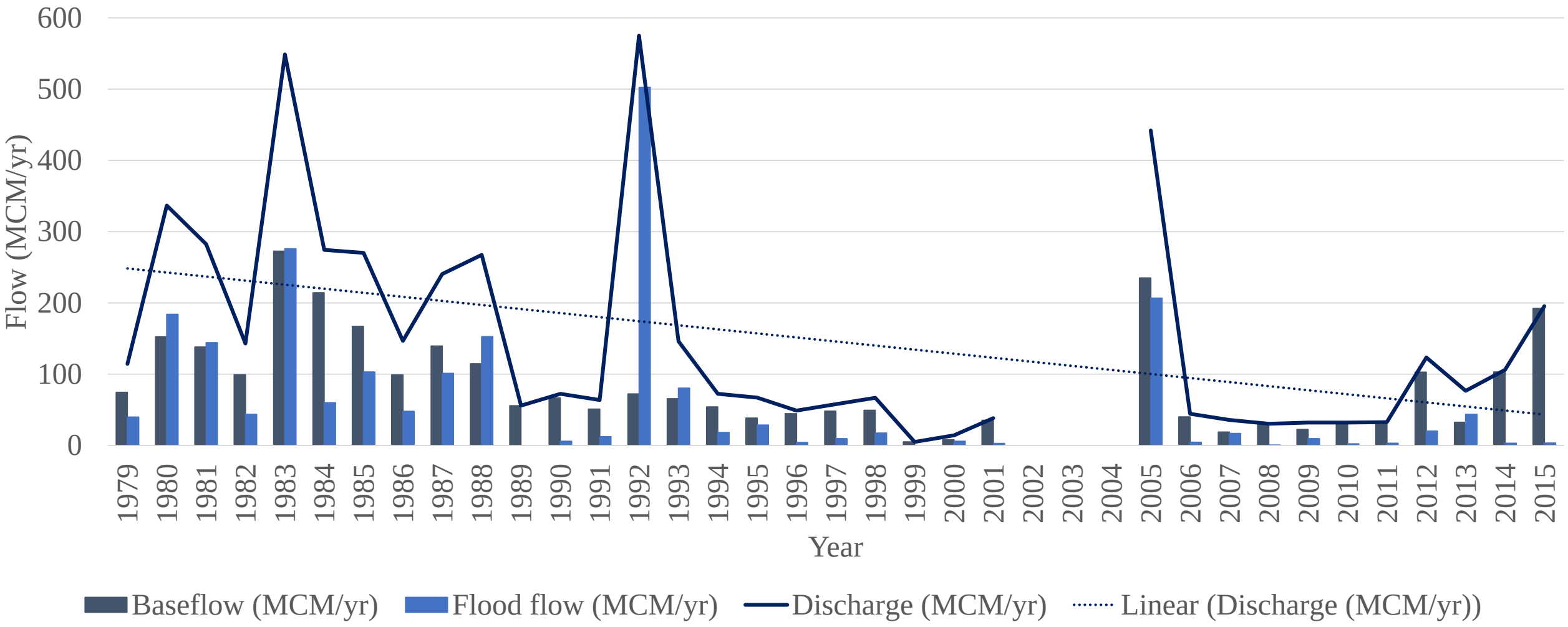
Average Rainfall (1981 – 2008)

- Ground data from 13 stations (Good and Moderate fit)
- Average 273 mm/yr (2016.51 MCM/yr)
- After BIAS correction of CHIRPS data (BIAS = 11%, RMSE error = 57mm)



Flow


(Sea of Galilee)
Avne Etan
Wadi Raqqad
Legend
Gauges (JVA)
Gauges (HSI)


600
500
400
300
200
100
0
Flow (MCM/yr)
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
Year
Baseflow (MCM/yr)
Flood flow (MCM/yr)
Discharge (MCM/yr)
Linear (Discharge (MCM/yr))


Al Taybeh
Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Reduction of flow

Many factors:

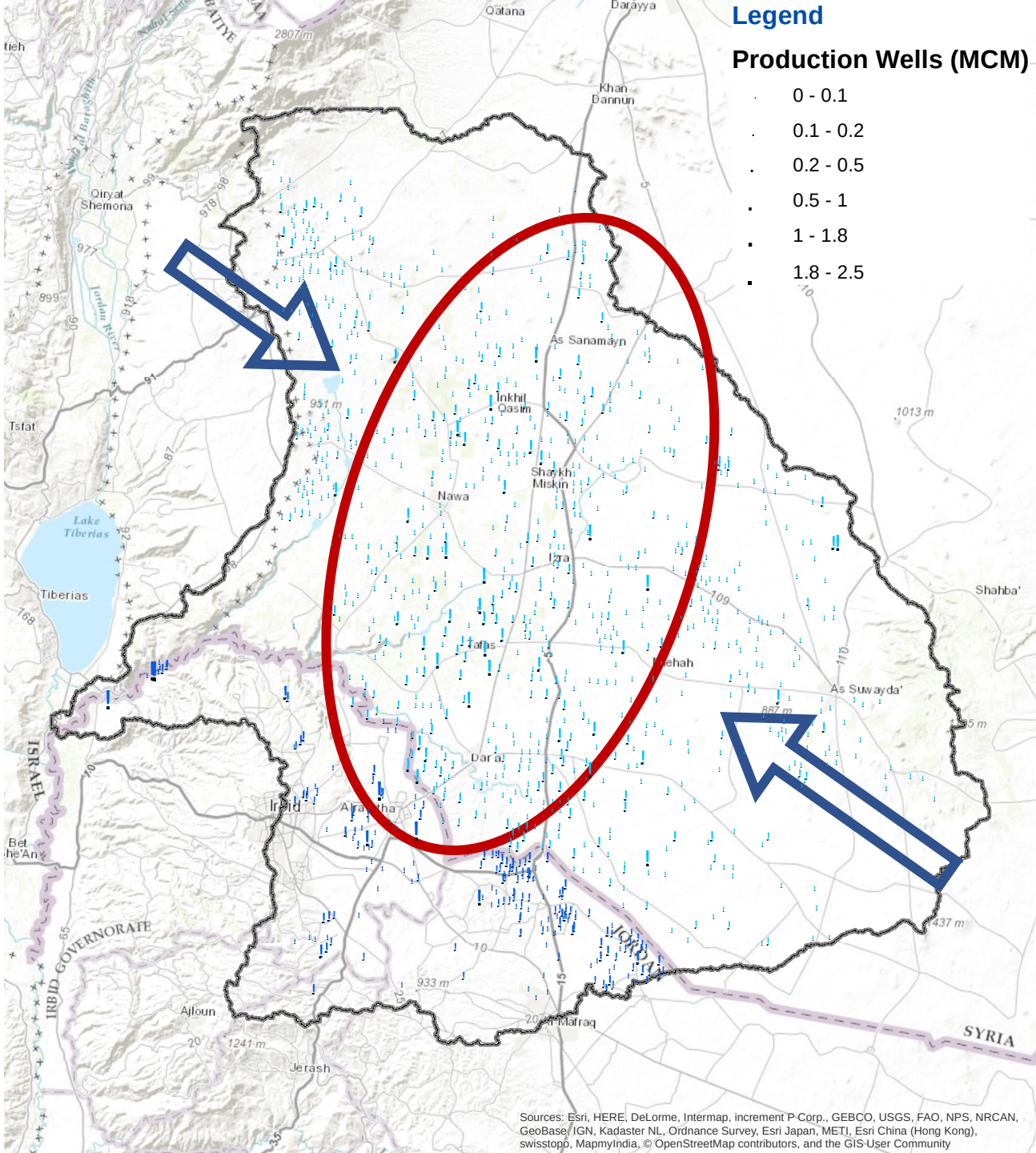
- Intensification of irrigated agriculture
- Infrastructure (dams, wells, etc.)
- Climatic Variation\Change

Production Wells

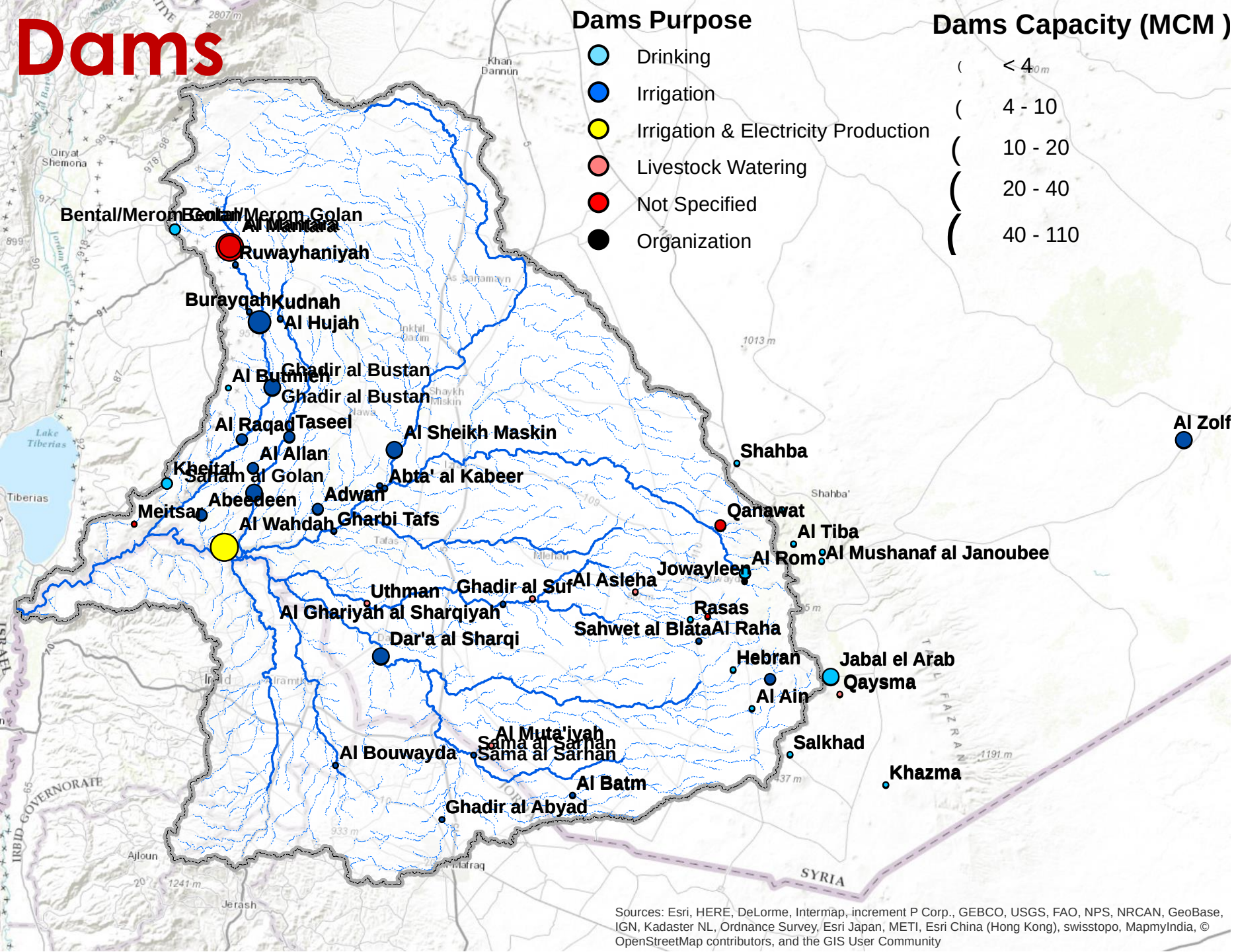
Syria
~ 154 MCM from 1,000 wells
basalt aquifer
Mainly in the middle of the basin

Jordan
~ 40 MCM from 200 wells
A7/B2 aquifer

More is actually pumped in both countries (illegal and unmonitored wells)



Dams



Sources: Esri, HERE, DeLorme, Intermap, increment P Corp., GEBCO, USGS, FAO, NPS, NRCAN, GeoBase, IGN, Kadaster NL, Ordnance Survey, Esri Japan, METI, Esri China (Hong Kong), swisstopo, MapmyIndia, © OpenStreetMap contributors, and the GIS User Community

Inside Yarmouk:
40 dams
~ 328 MCM

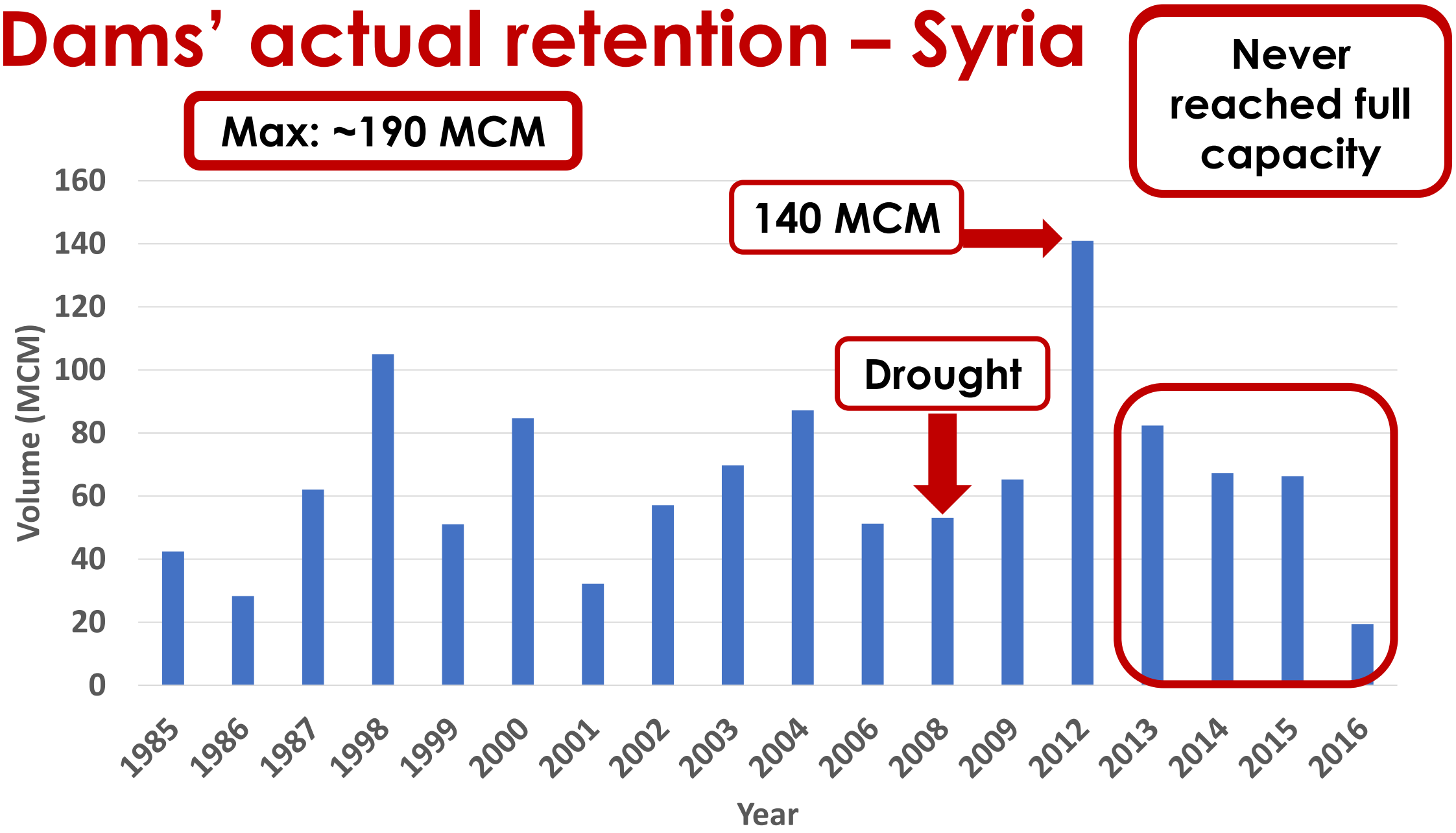
Polluted:
13 dams
~ 63 MCM

Dams' actual retention

- Volume-area relation from Landsat images (Liebe et al., 2005)
- V = A x D / 3
- 34 images processed
- Between 1985 – 2016
- Spring (April) and Summer (August) seasons


Taseel
Al Sheikh Maskin

Dams' actual retention – Syria



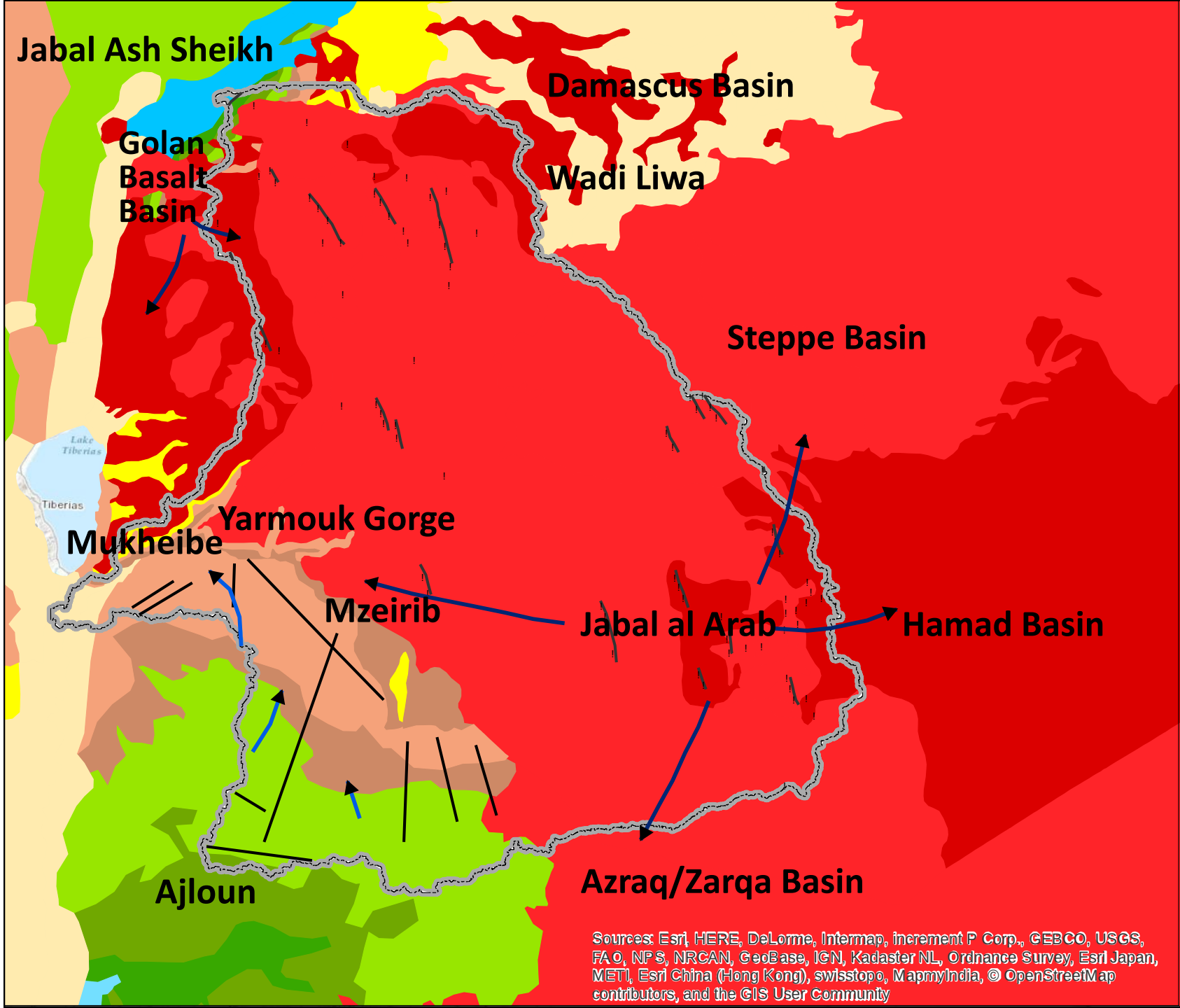
Geology

Legend

- Extinct Volcanoes in Syria
- Faults in Jordan
- Faults in Syria
- Yarmouk Watershed

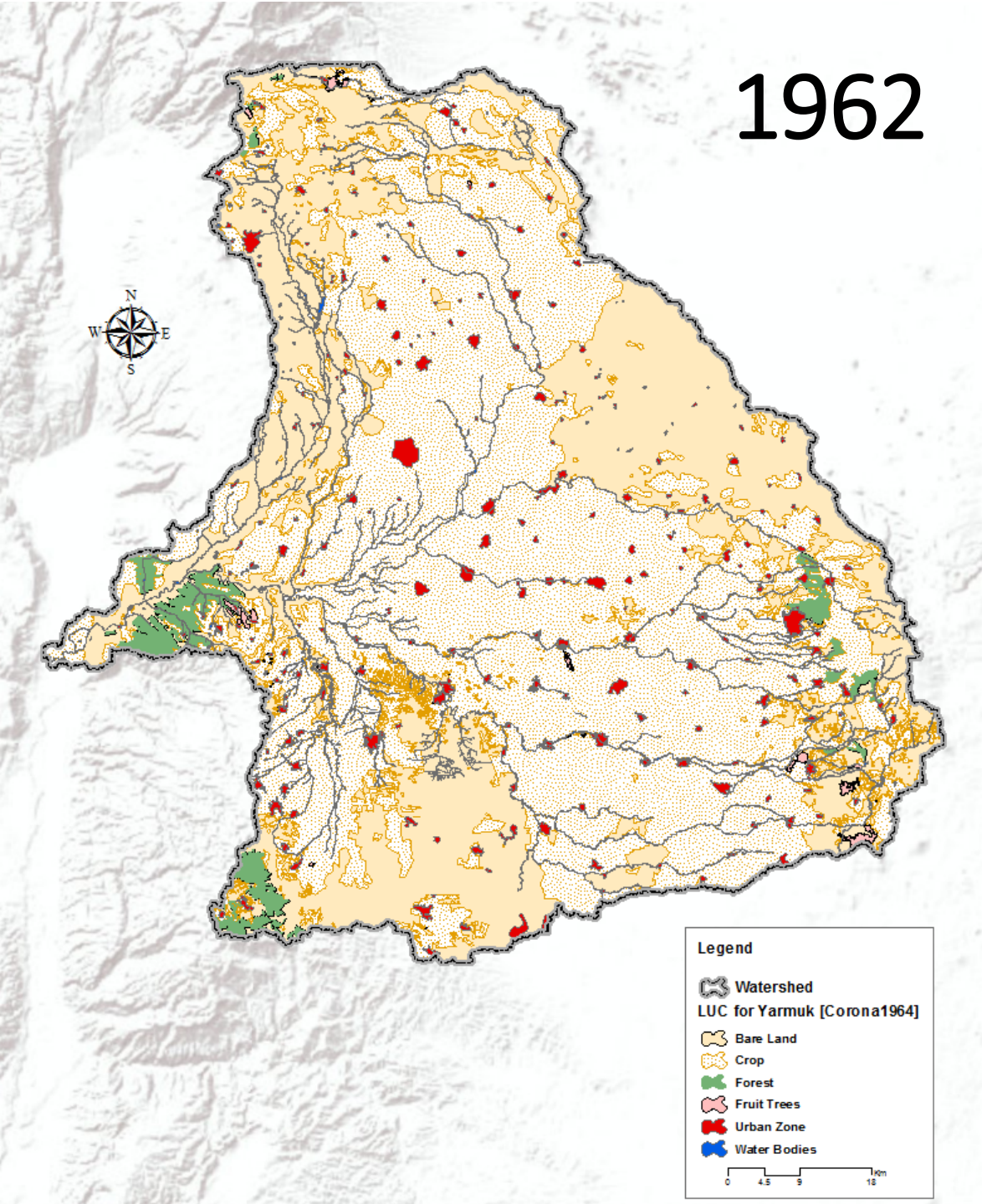
Geology

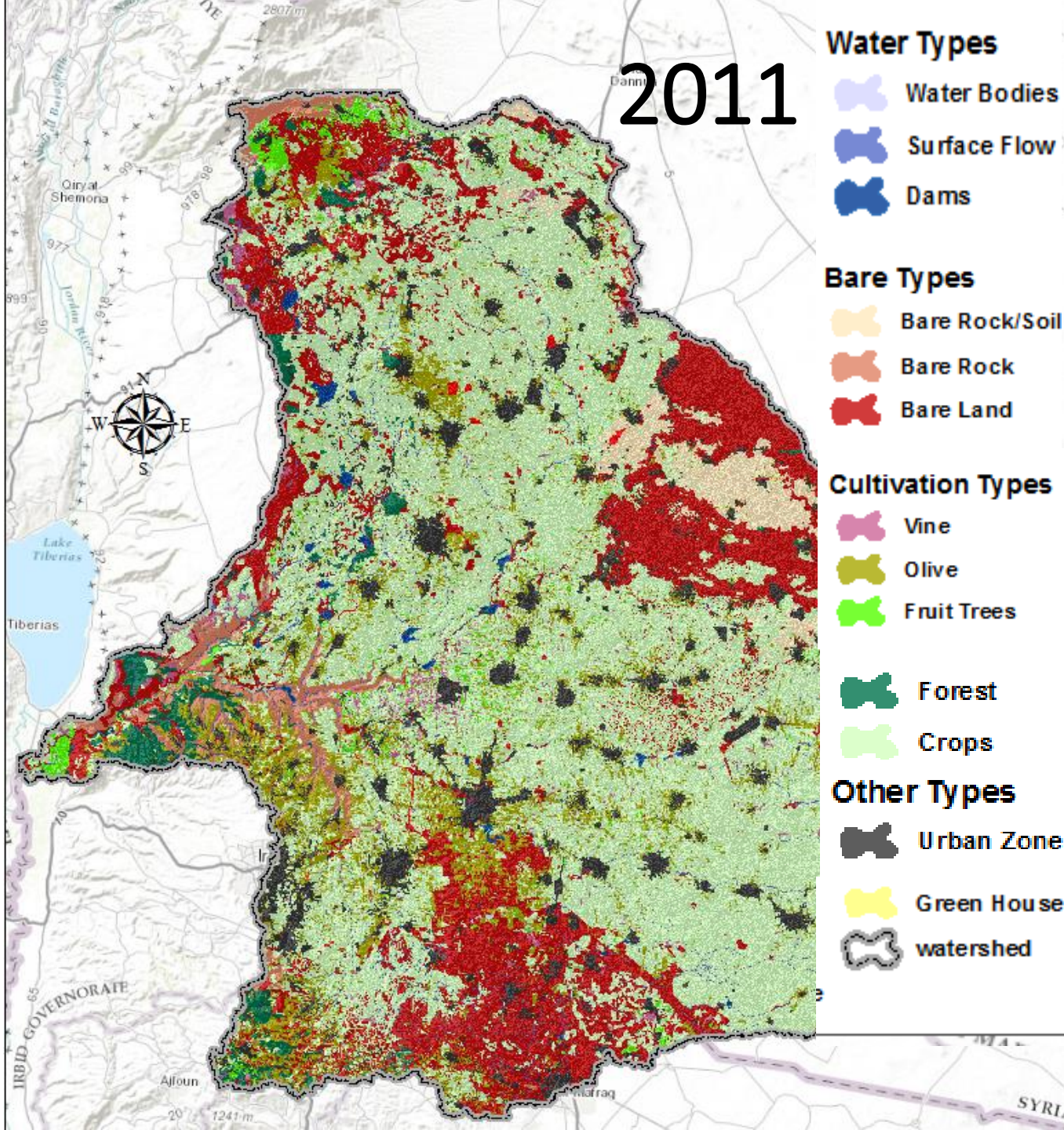
- Quaternary Basalts
- Neogene Basalt
- Quaternary Deposits
- Neogene
- B4/B5 - Pg2-2/Pg2-3
- B3 - Pg1-Pg2-1
- A7/B2 - Cr2cn cp/Cr2m-d
- A1/A6 - Cr2cm-t
- K - Cr1-Cr2t
- Jurassic
- Zarqa Group

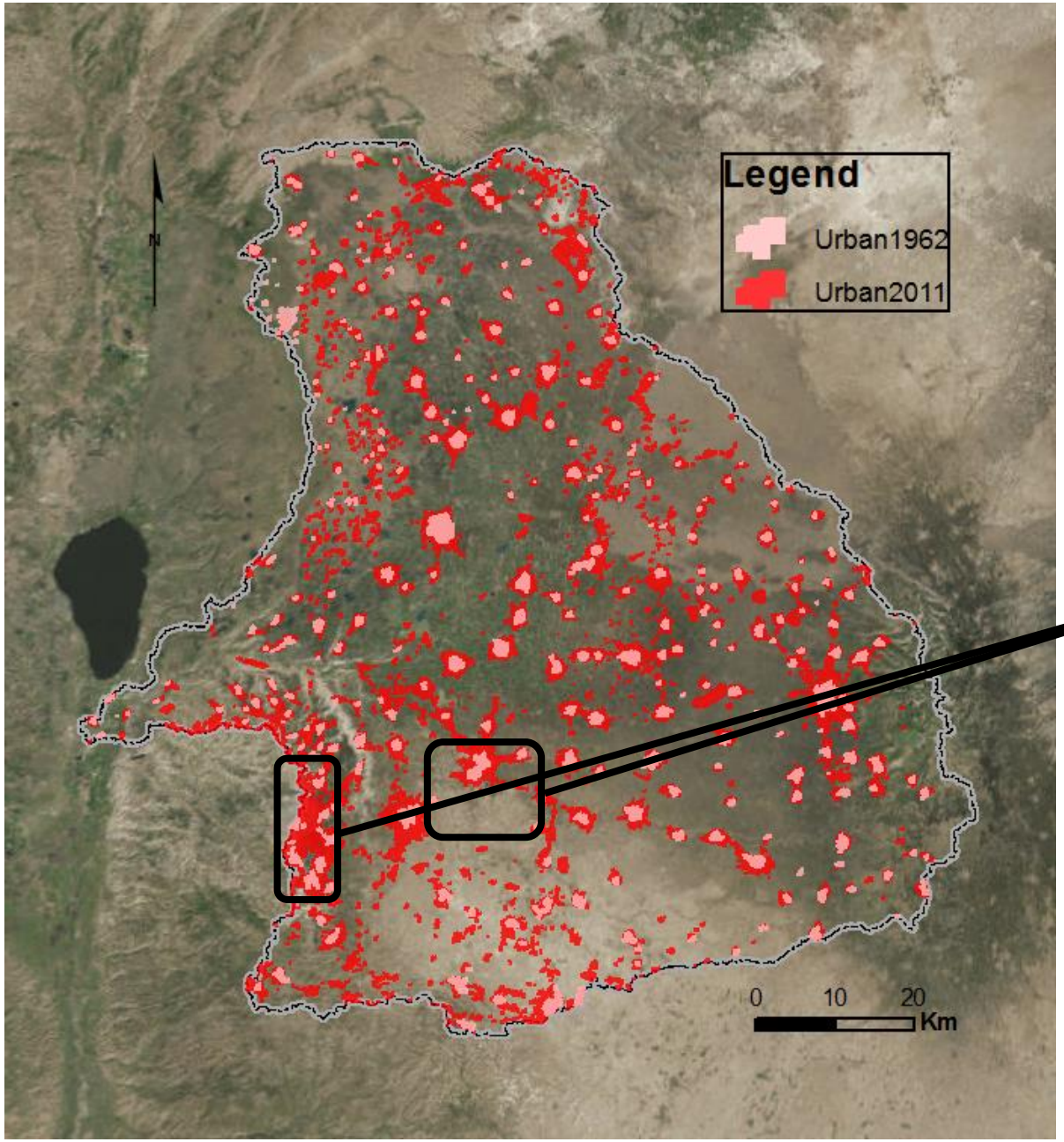


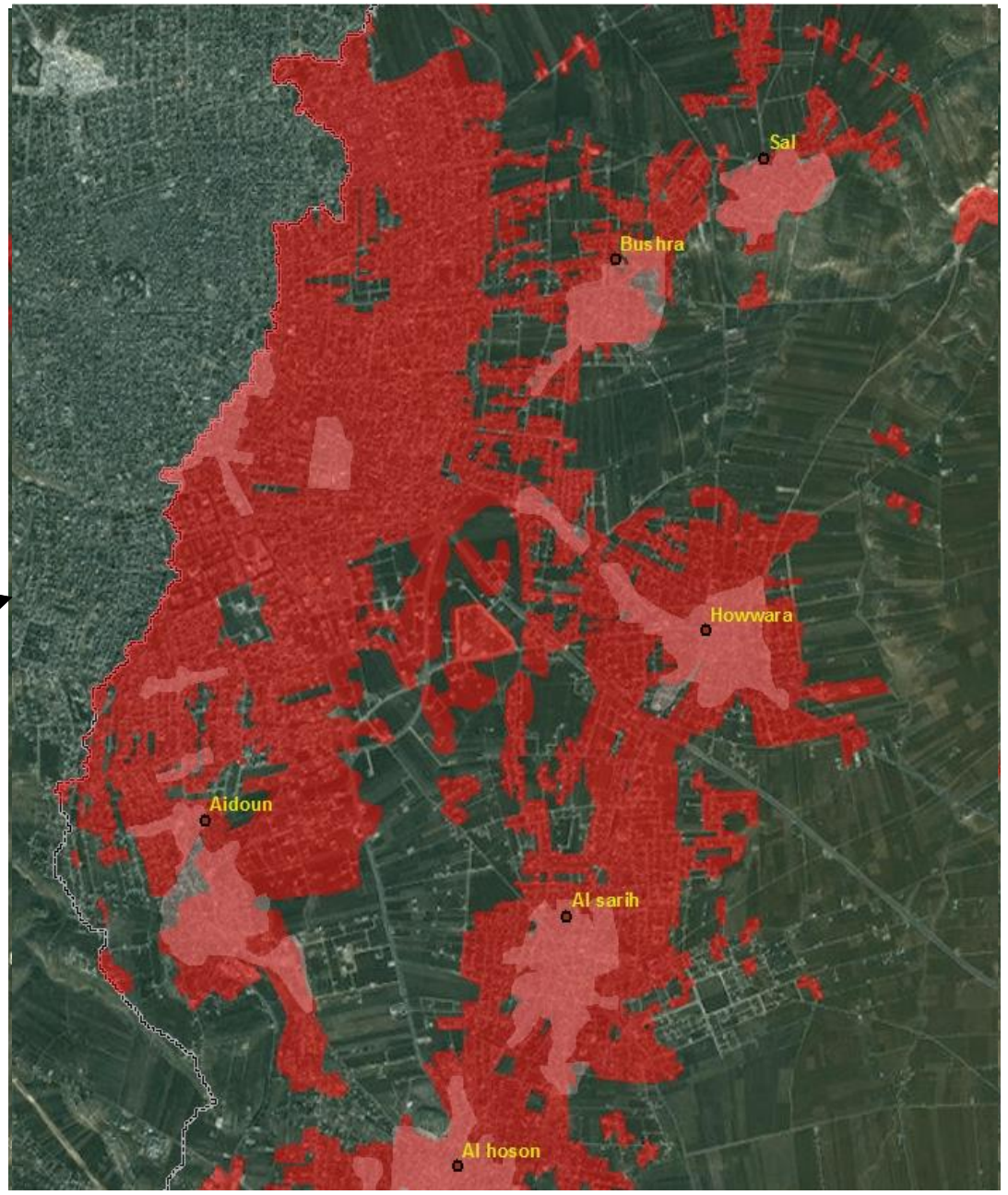
Hydrogeology

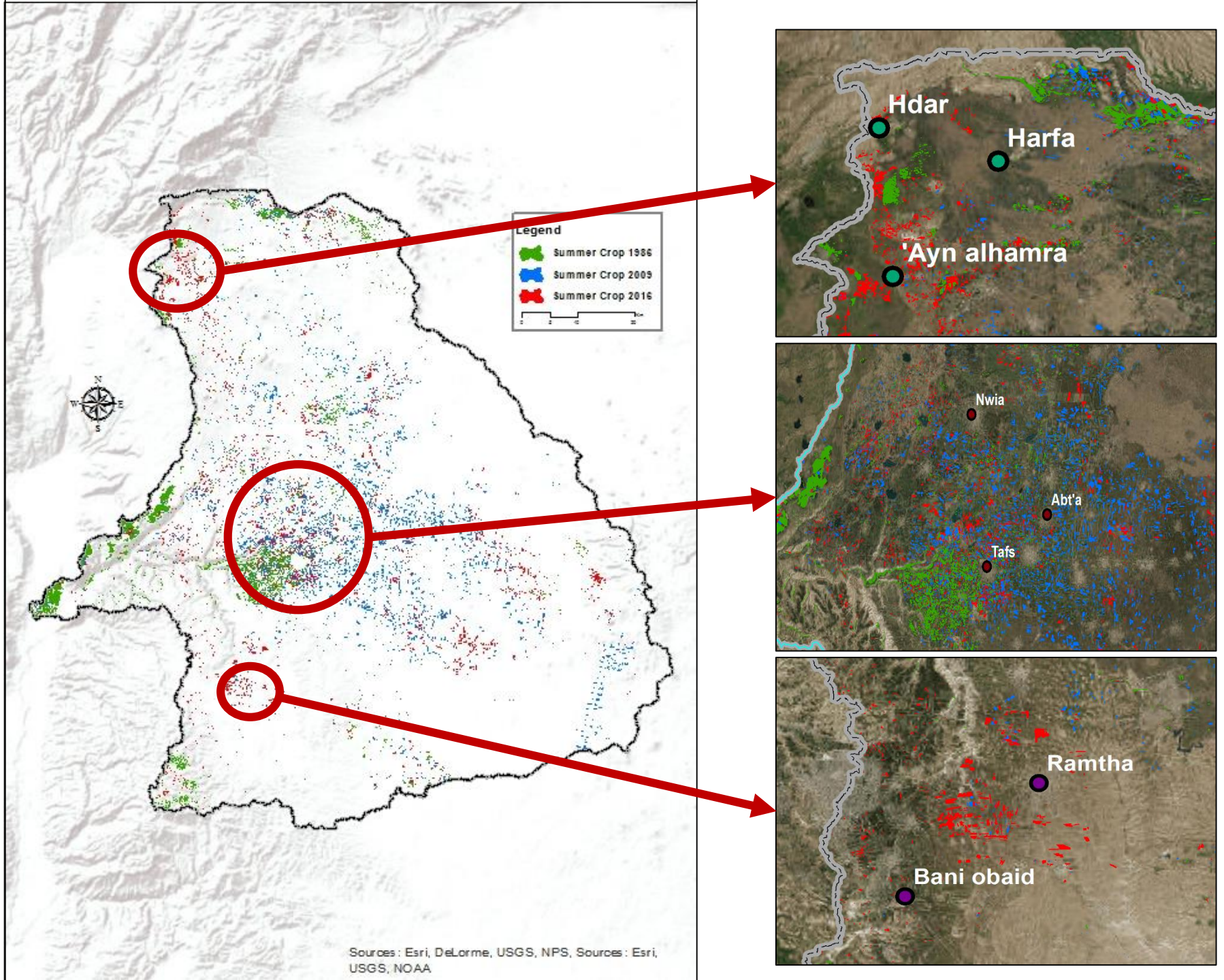
System	Formation	Code	Age	Lithology	Type
Upper Aquifer	Basalt		Neogene - Quaternary	basalt	Aquifer
	Um Rijam/Wadi Shallala	B4/B5 – Pg_2^2 /Pg_2^3	Eocene	limestone, marl	Aquifer
	Muwaqqar	B3 – Pg_1-Pg_2^1	Paleocene	marl, chalky limestone	Aquitard
Middle Aquifer	Wadi As Sir/Amman - Al Hissa	A7/B2 – Cr_2cn cp/Cr_2m-d	Coniacian - Maastrichtian	chalky, dolomitic limestone	Aquifer
	Naur / Shueib	A1/A6 – Cr_2cm-t	Cenomanian – Coniacian	Marl, Chalky Limestone	Alternation
Deep Aquifer	Kurnub	K – Cr_1-Cr_2 t	Lower Cretaceous	Sandstone	Aquifer


1962
N
W
E
S
Legend
Watershed
LUC for Yarmuk [Corona1964]
Bare Land
Crop
Forest
Fruit Trees
Urban Zone
Water Bodies
0
4.5
9
18
Km


2011
Water Types
Water Bodies
Surface Flow
Dams
Bare Types
Bare Rock/Soil
Bare Rock
Bare Land
Cultivation Types
Vine
Olive
Fruit Trees
Forest
Crops
Other Types
Urban Zone
Green House
watershed
Qiryat Shemona
Lake Tiberias
Tiberias
IRBID GOVERNORATE
Ajloun
N
W
E
S


Legend
Urban1962
Urban2011
N
0
10
20
Km


Sal
Bushra
Howwara
Aidoun
Al sarih
Al hoson


Legend
Summer Crop 1986
Summer Crop 2009
Summer Crop 2016
Hdar
Harfa
'Ayn alhamra
Nwia
Abt'a
Tafs
Ramtha
Bani obaid
Sources : Esri, DeLorme, USGS, NPS, Sources : Esri, USGS, NOAA

Crop water requirement

Data collection
Using SPOT processed images

→

NDVI calculation
NDVI = NIR – Red /NIR + Red

→

ET0 calculation
According to Penman–Monteith equation

↓

Kc computation
kc = 1.25*NDVI +0.2

→

Fc calculation
Fc = (NDVI – NDVI (min))/(NDVI(max)-NDVI(min))

→

Kr estimation
takes into account when % of fc is ≤ 50 %.

↓

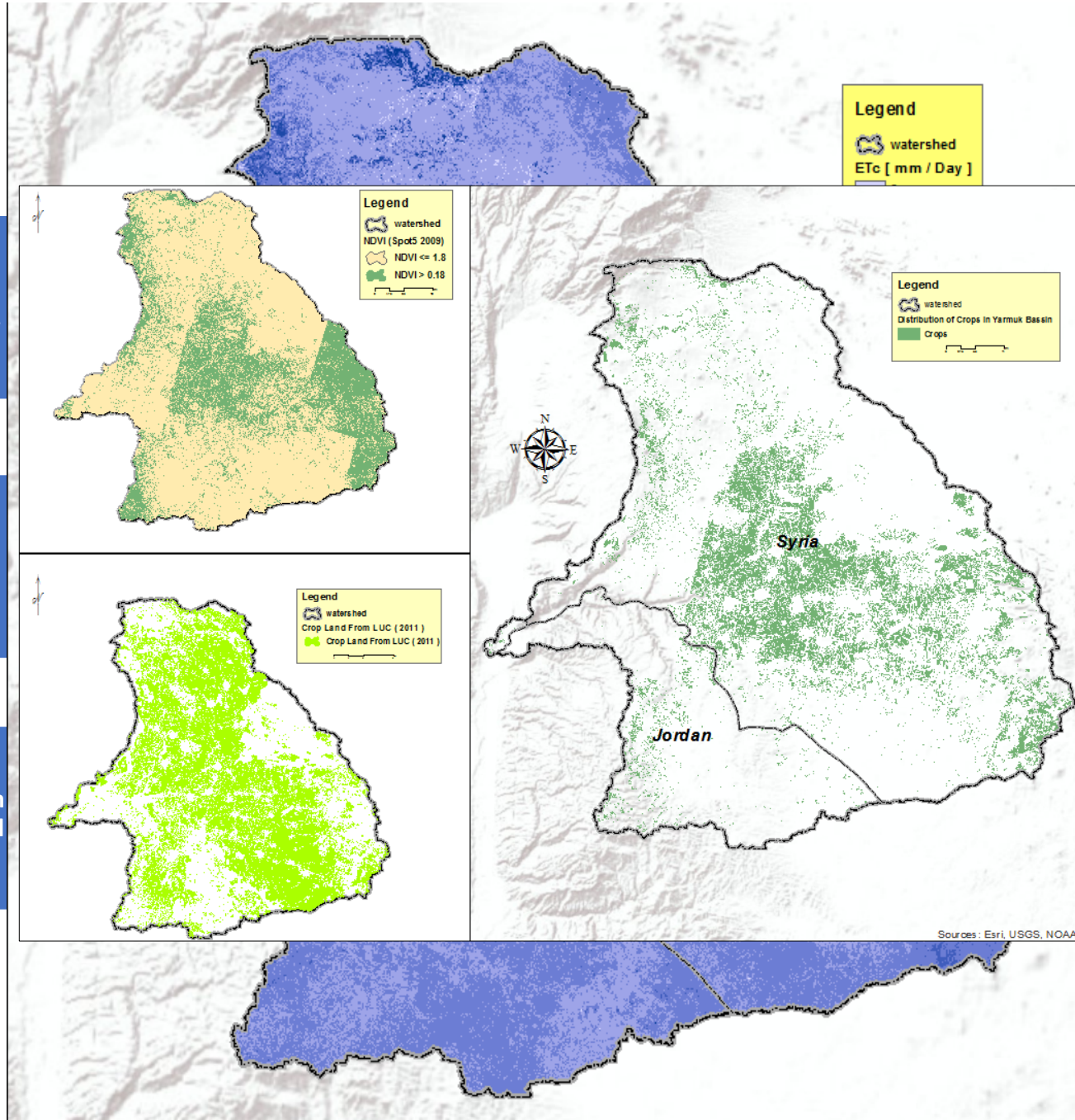
ETc calculation
ETc = Kc * Kr * ET0

→

Generate vegetation zone
intersecting LUC Crop-Land and NDVI>0.18 for green areas

→

CWR calculation
CRW (MCM) =[(ΣETC In vegetation Zone)*Pixel Size*nb of irrigation Days] /10^9



شـــــــــــــــــــــــــــــــكـــــــرًا

لحضـــــــــــــــــــــــــــــــوركم