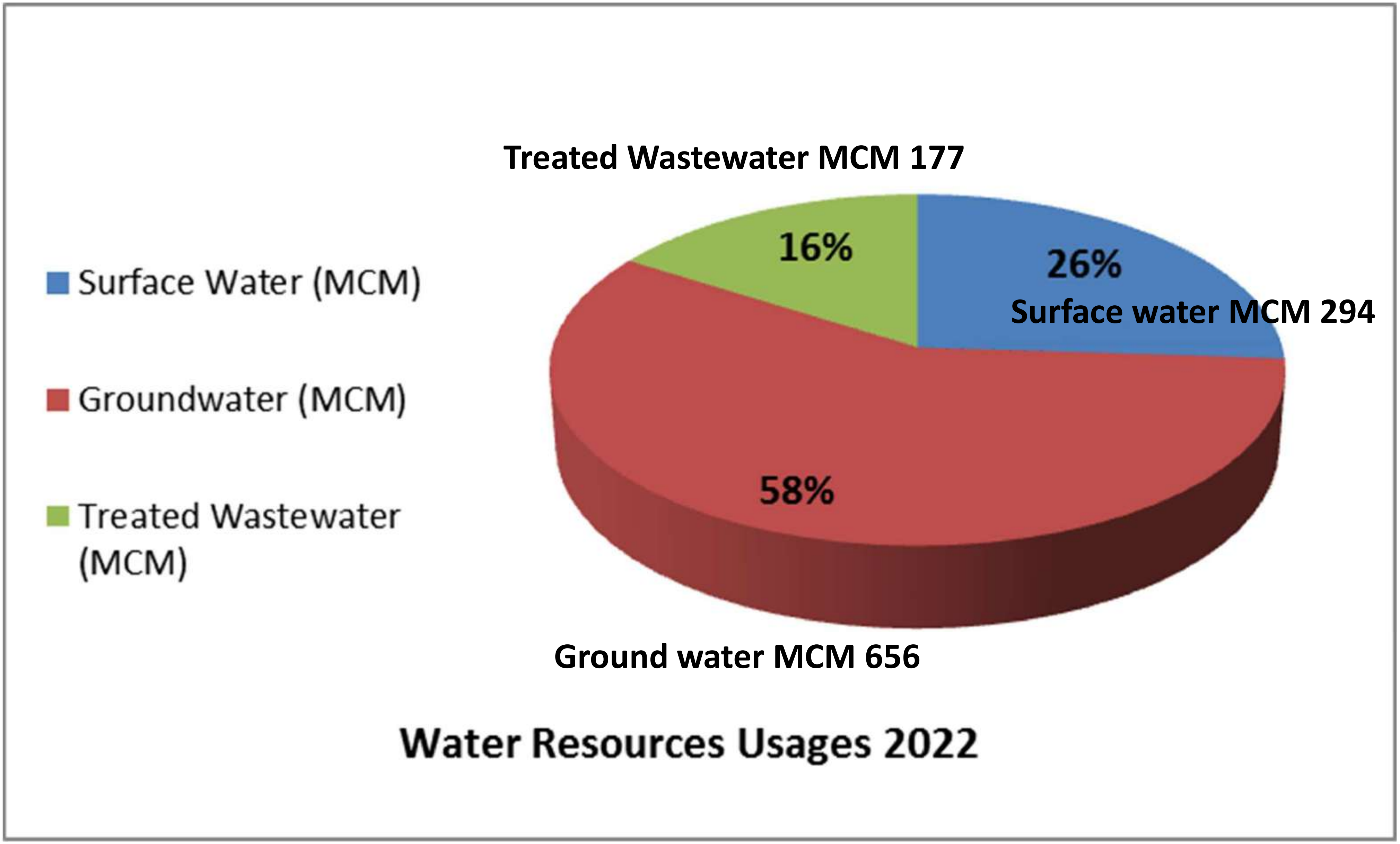
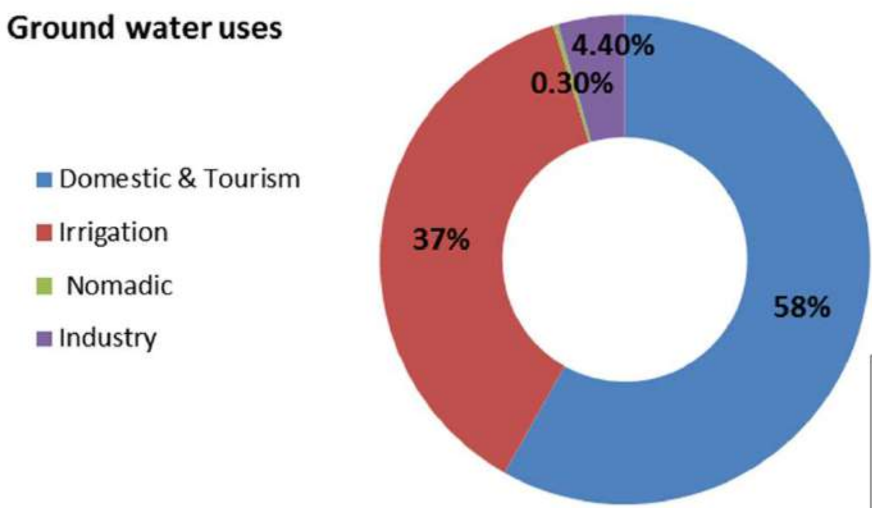
Ministry of Water and Irrigation

وزارة المياه والري

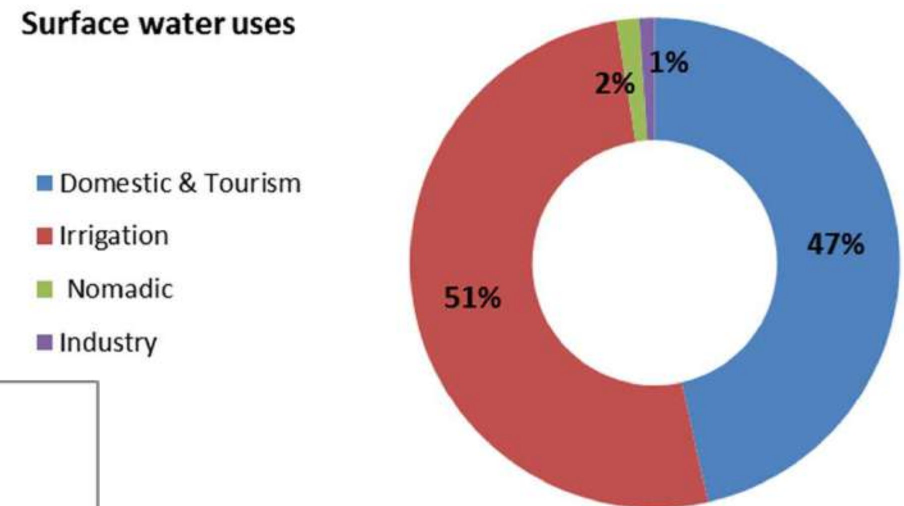

Remote Sensing for crop mapping and
assessment for groundwater abstraction
Geo. Ala'a Atieh



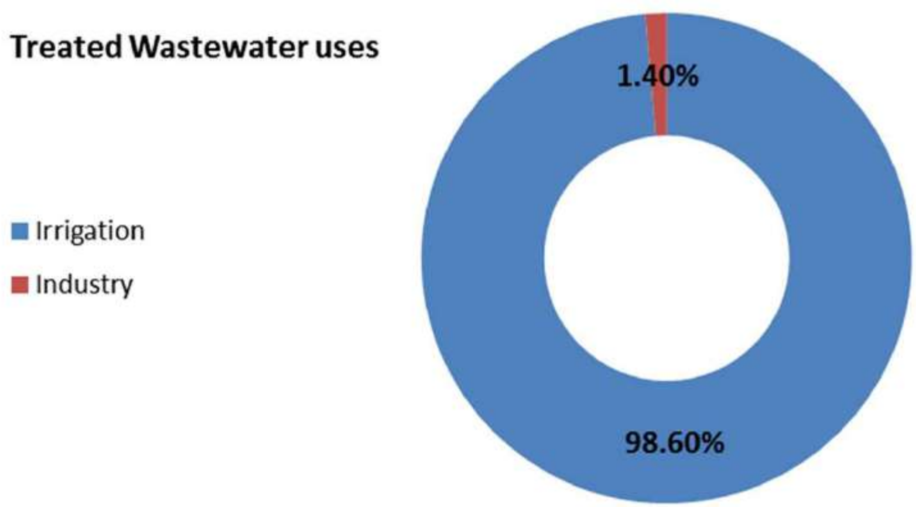
The kingdom depends basically and heavily on the ground water resources to provide the needs of all sectors by about 58% (2022)



Ground water MCM 656



Surface water MCM 294

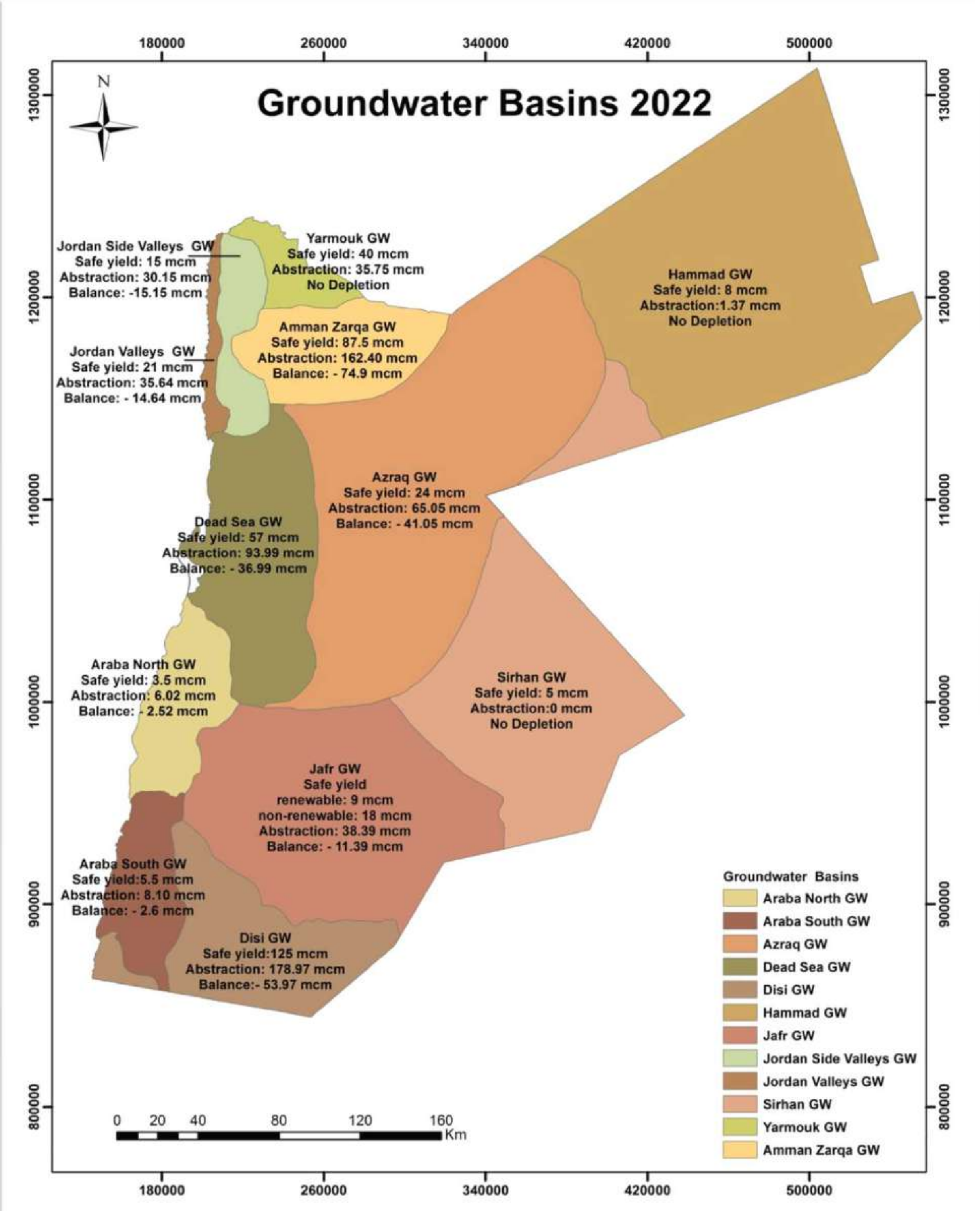


Treated Wastewater MCM 177

Irrigated agriculture consumes about 60% of the available water resources in Jordan

Groundwater is the major source for irrigated agriculture in highlands that host 70% of the irrigated lands in Jordan

In the last few years
Groundwater depletion and illegal access to water have been reported in many locations in the irrigated highlands



depletion of groundwater basins due to over-pumping

Groundwater Basin	Safe Yield (MCM)	Abstraction (MCM)	Deficit (MCM)
Disi & Mudawara	125	178.97	-53.97
Amman-Zarqa	87.5	162.4	-74.9
Yarmouk	40	35.75	4.25
Jordan Side Valley	15	30.15	-15.15
Azraq	24	65.05	-41.05
Jafer	27	38.39	-11.39
Jordan Valley	21	35.64	-14.64
Dead Sea	57	93.99	-36.99
Araba South	5.5	8.1	-2.6
Hammad	8	1.37	6.63
Sirhan	5	0	5
Araba North	3.5	6.02	-2.52

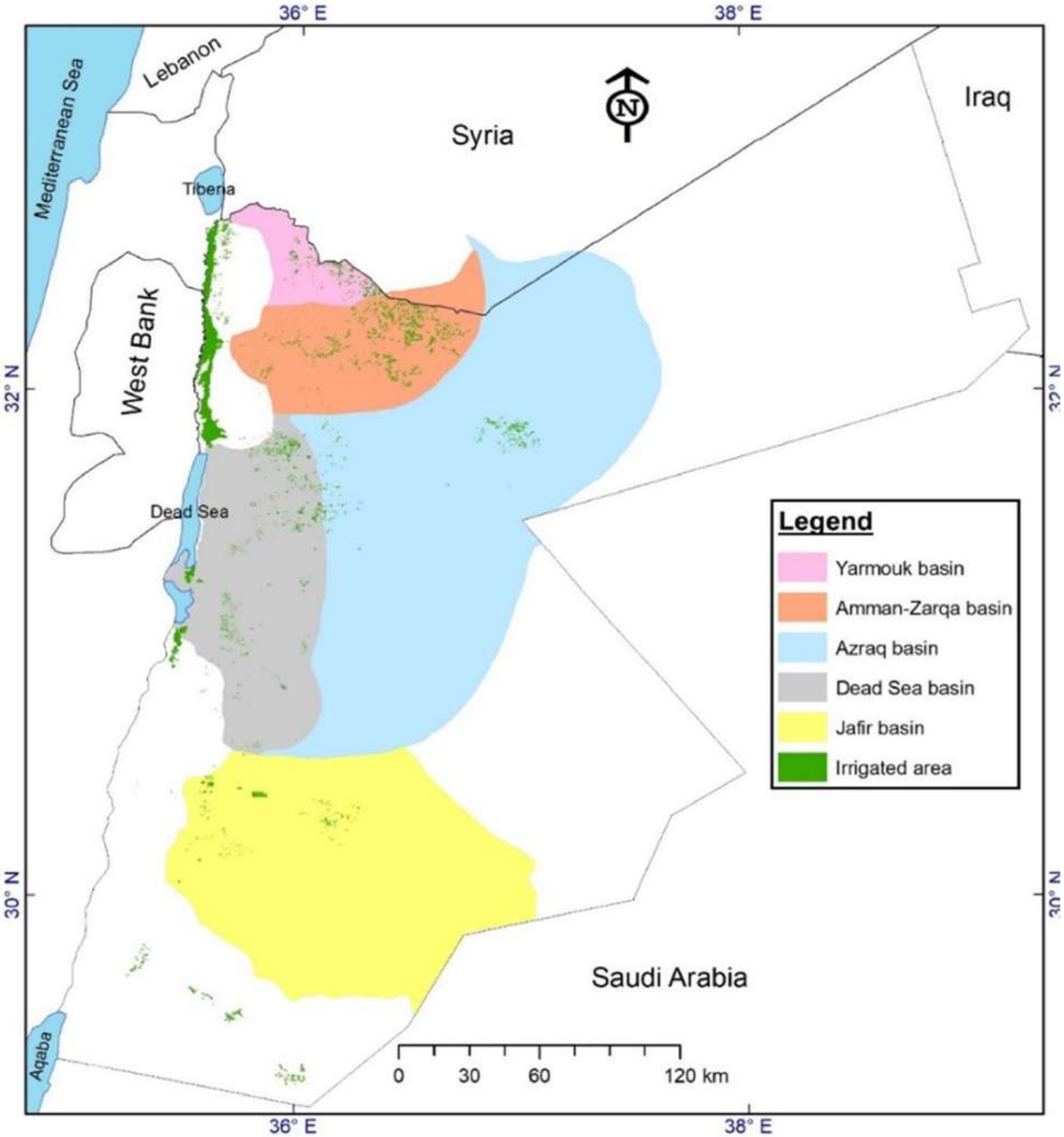
Number of Backfilled Illegal wells 2012-2022

Year	Number of Wells
2012	19
2013	141
2014	562
2015	174
2016	167
2017	177
2018	111
2019	74
2020	37
2021	67
2022	71

Therefore, improving groundwater monitoring tools will contribute to the efforts of the Ministry of water and Irrigation (MWI) in managing the scarce water resources of the country

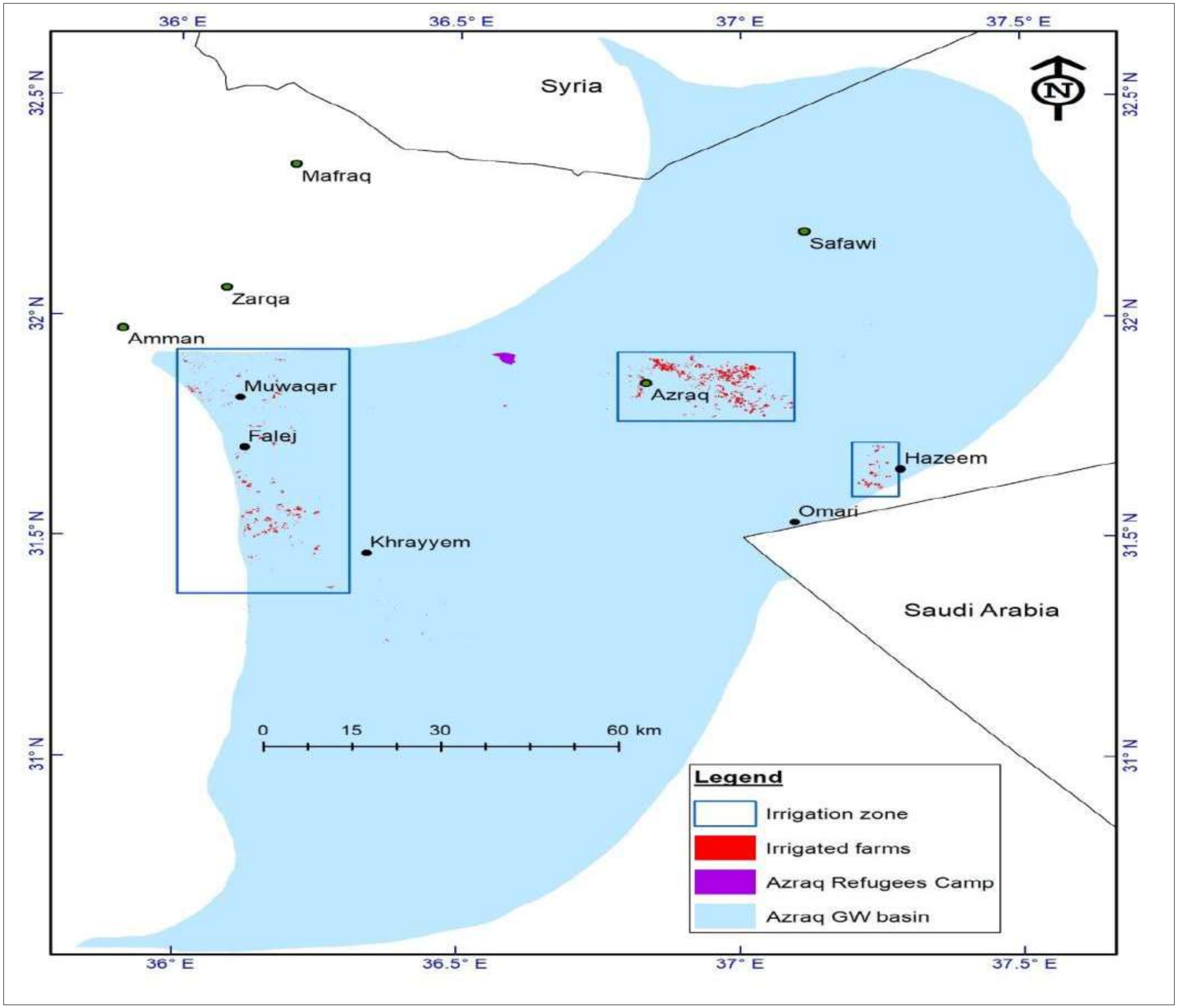
As part of its support to MWI efforts, the USAID water management initiative (WMI) is working with Ministry of Water and Irrigation (MWI) and Water Authority of Jordan (WAJ) to develop the current groundwater monitoring aspects using Remote Sensing (RS) Techniques

The general objective of RS work is to prepare maps for irrigated crops and their water consumption



Mapping of irrigated crops and their water consumption was carried out for five basins in Jordan's highlands Yarmouk, Amman-Zarqa, Azraq, Dead Sea and Jafer

AZRAQ BASIN



Location of the Azraq basin and distribution of irrigated areas (red color) inside the basin during October 2016-September 2017.

The annual safe yield of only 24 million cubic meters (MCM)

OVERVIEW OF IMPLEMENTED REMOTE SENSING METHODOLOGY

The remote sensing methodology for mapping crops and their water consumption was based on the use of remote sensing data of Landsat 8, hourly and daily weather records to derive maps of ETa using the SEBAL model

The SEBAL-ETa, representing NIWR, was transferred to GIWR using an overall irrigation efficiency of 50%.

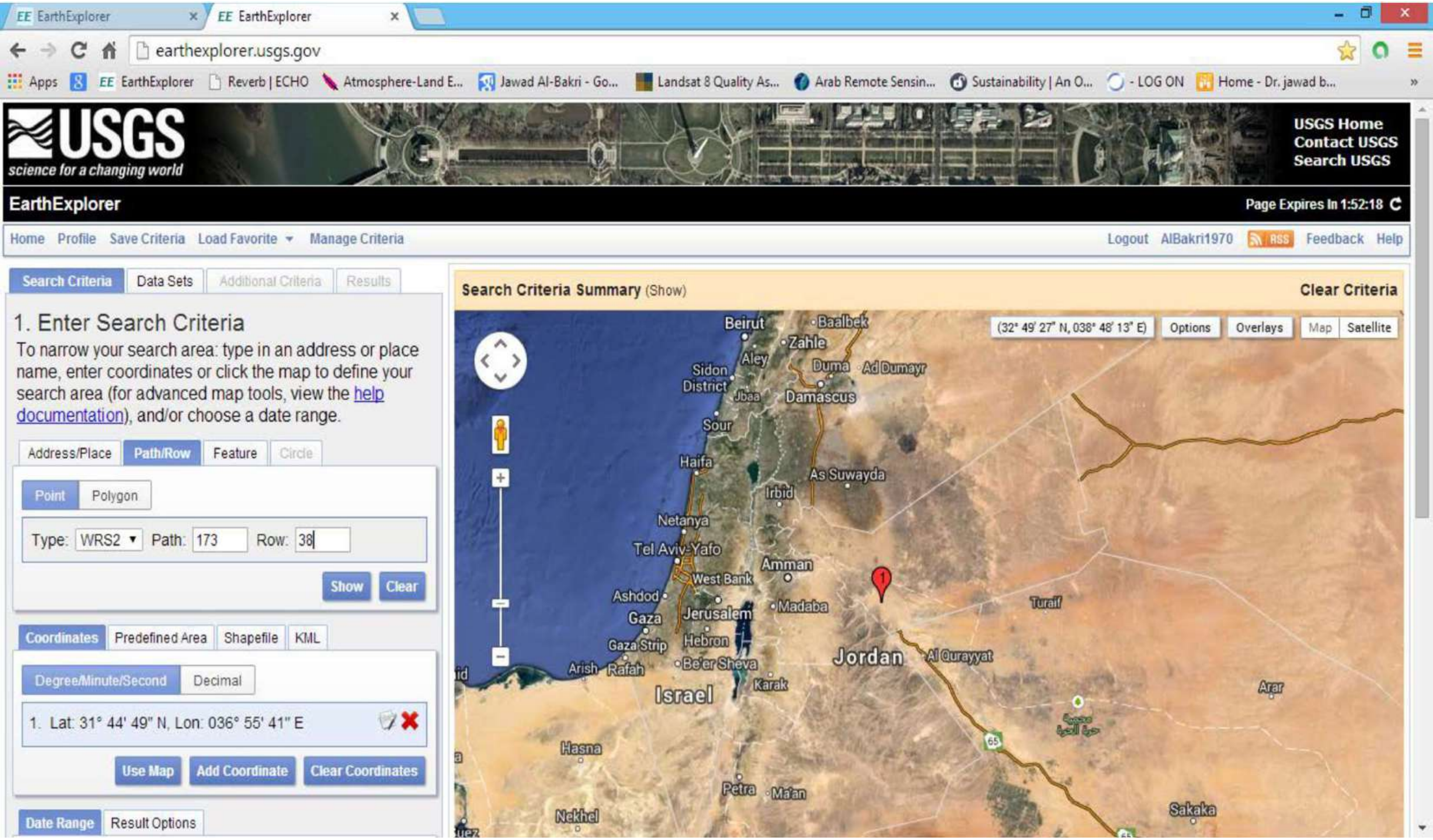
The maps of ETa were refined and overlaid by the maps of crops that were derived from remote sensing of Landsat 8.

The method of crop mapping was based on the use of a time series satellite images of Landsat 8 with a medium spatial resolution (30m) to derive multi-temporal series of the normalized difference vegetation index (NDVI), which was then used to detect and classify the main irrigated crops

Results were then verified with observations collected during the field visit to the basin, high resolution images of GE and previous data

Processing of Remote Sensing Data

Remote sensing data of Landsat 8 were downloaded directly from the USGS Earth Explorer portal (http://landsat.usgs.gov/)



The images were downloaded for the period October 2016-Septmeber 2017; which is the same period used by the MWI to calculate the annual water budget for year 2017

The selection of images included cloud free data with at least one image for one month

The partly cloudy images were also processed and cloudy areas were interpolated using the image processing software

The set of downloaded images included the surface reflectance data of visible and infrared bands and the thermal band

Mapping Irrigated Crops

Digital classification of multi-temporal layers of NDVI was used to derive the map of irrigated crops

The layers of NDVI were generated from the images of Landsat 8 using ERDAS Imagine software

The output NDVI layers, produced during application of SEBAL, were stacked in one file with layers sequentially arranged according to date of acquisition

derive a map with 15 spectral classes of vegetated and non-vegetated areas in Azraq basin

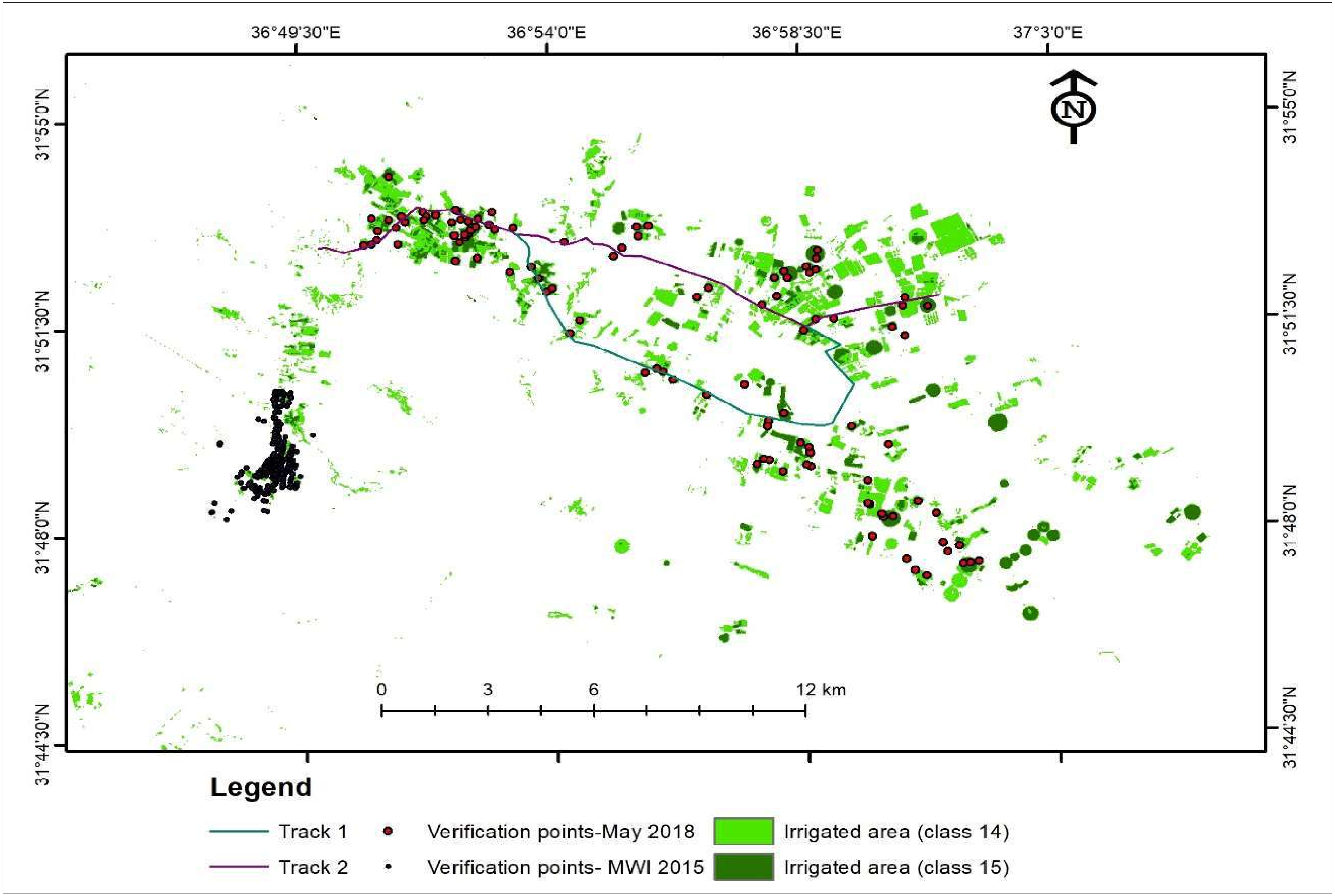
Classes 14 and 15 were representing the irrigated areas, while class 12 was representing some of the irrigated areas and fallow fields , cultivated in previous year

The map of irrigated crop was merged with the map of ETa to obtain the map of irrigated areas

The final map of irrigated crops was then verified by a field visit in which type of crop, irrigation systems and growth stages were recorded for irrigated farms using specified tracks inside the basin

Observations of water conveyance and storage were also recorded

Map of irrigated areas and tracks of field visit for verifying irrigated crops in Azraq.



Mapping Crop Water Consumption

SEBAL was used to map actual evapotranspiration (ETa) for the irrigated crops

Using ground data, ETa map that represented NIWR was transferred into GIWR

To assess the overall water consumption by the different irrigated crops
This would require the use of overall irrigation efficiency of 50%
or calibrate the model with ground data

Then compared with records of groundwater abstraction

Processing of Climatic Data

Application of SEBAL model requires processing of climatic data to derive hourly and daily reference ET, known as ETr.
Data of air temperature, wind speed, relative humidity, solar radiation and sunshine hours were obtained from Jordan Meteorological Department (JMD).
Missing data of solar radiation were downloaded from the NASA Climatology Resource for Agro-climatology (http://power.larc.nasa.gov/cgi-bin/cgiwrap/solar/agro.cgi).

The map of ETa included both rainfed and irrigated areas in addition to water bodies and wadis were water is stored or ponded

Therefore, the map of ETa was clipped by the map of irrigated crop to extract ETa for irrigated areas and to exclude other areas

Manual editing was applied to the map to remove non-irrigated areas that were included in the crop and ETa maps

The final map of irrigated areas was verified by observations collected during the field visit & high resolution images of GE & ground data of MWI and previous maps

The final map was used to derive total annual ETa and NIWR for the basin

Both of crop and ETa maps were intersected and a spatial join function was applied to calculate ETa for each crop type.

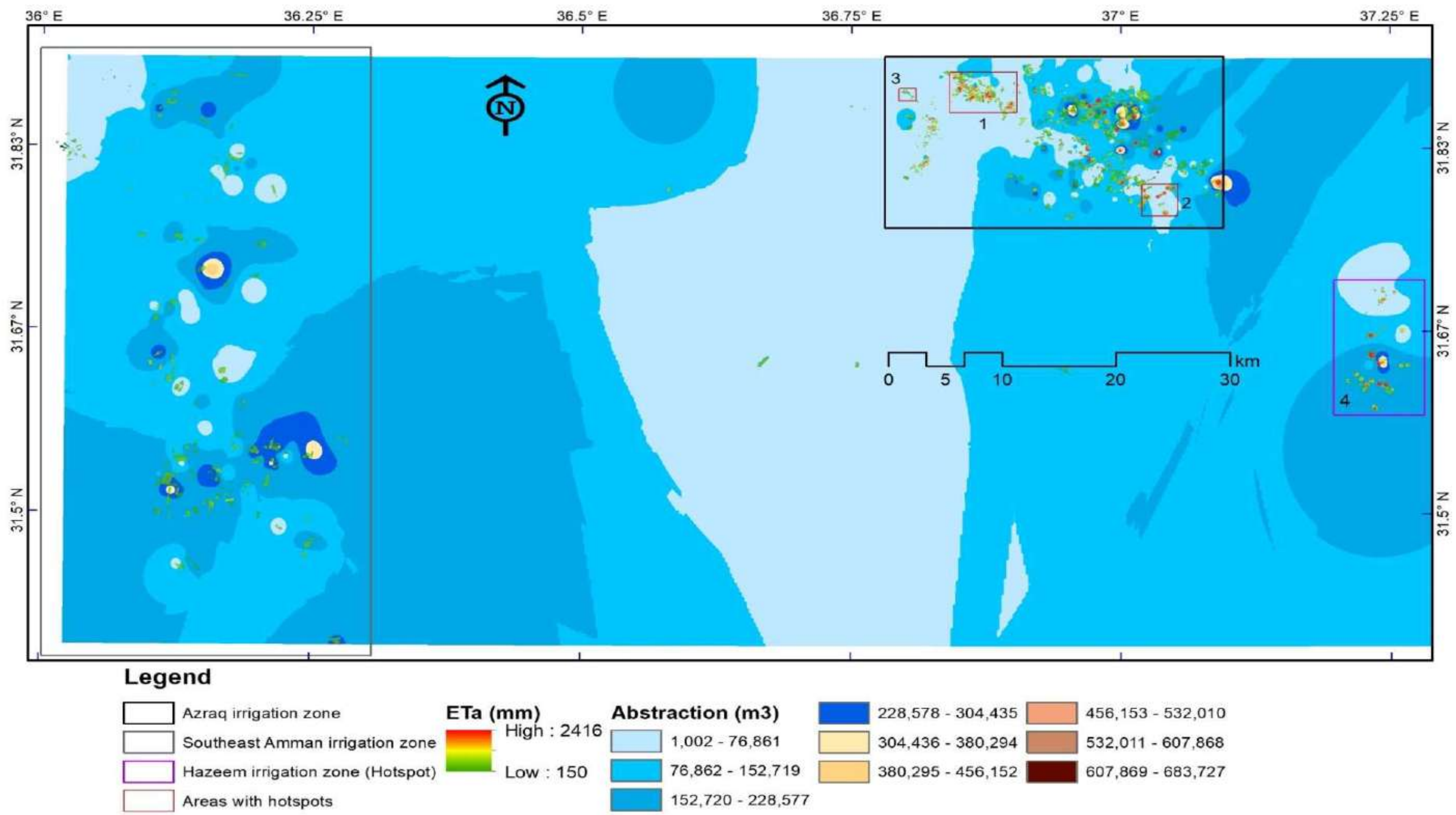
RESULTS

The total recorded abstraction in year 2017 was 49 MCM.

The results from this RS study showed that the gross amounts of water consumed by the existing cropping pattern were 60 MCM

Identification of Hotspots

The locations identified as hotspots represented irrigated areas where water consumption was higher than the recorded abstraction



Maps of ETa and recorded groundwater abstraction with locations of main hotspots of high water consumption

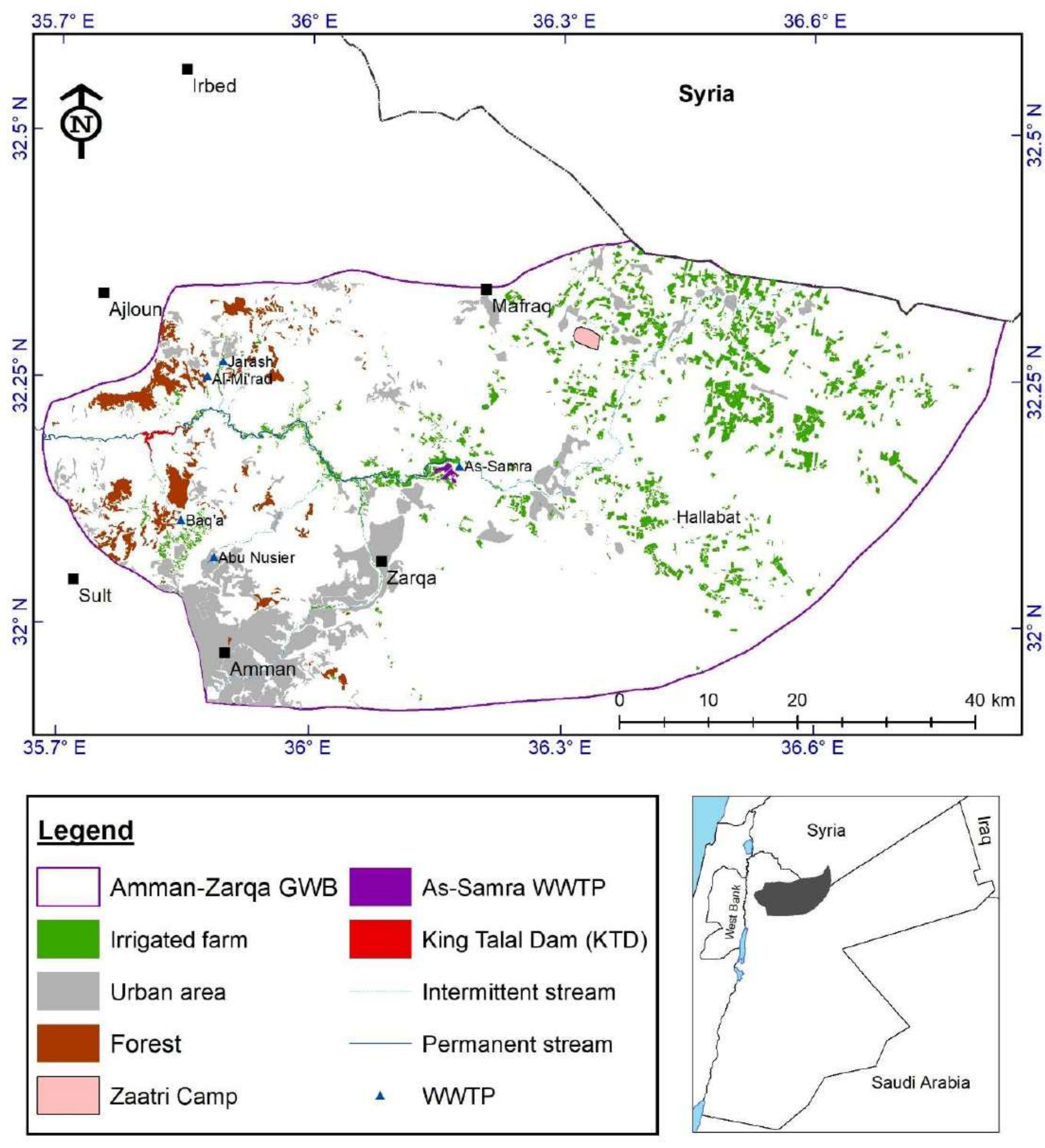
unlicensed wells or incorrect metering of groundwater

improper cropping patterns that consume high amounts of water

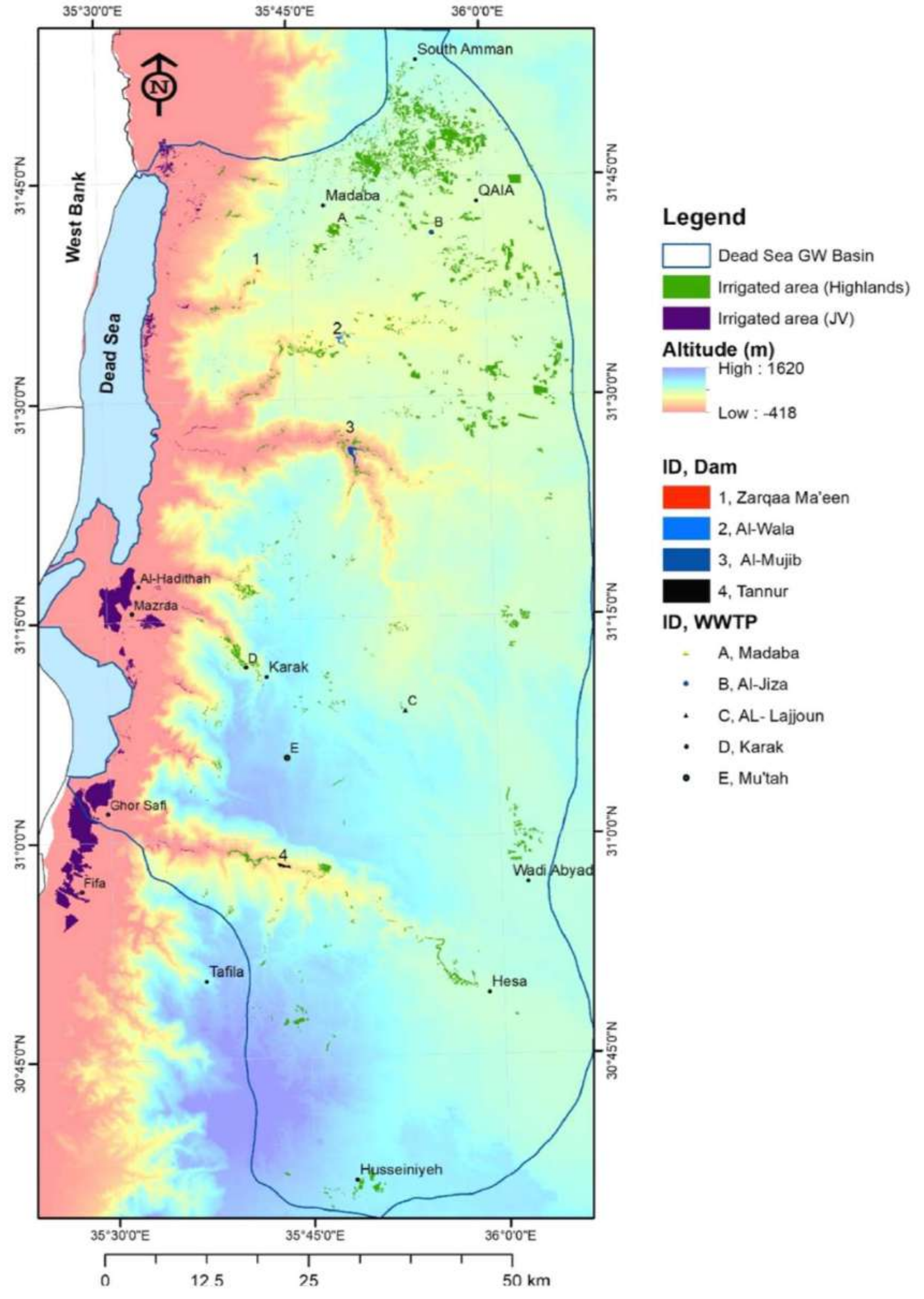
The hotspots with high water consumption would represent areas that interventions of water auditing and management should be implemented

Abstraction -Basin level recorded by MWI (2017)	**49 MCM**
Abstraction (Basin level) calculated from RS study	60 MCM
Possible water savings (MCM):	11-29 MCM
By water auditing and monitoring	11 MCM
By improving irrigation efficiency by 10%	6 MCM
By changing cropping patterns	12 MCM
Irrigated area in Oct. 2016-Sep. 2017 mapped from RS	73.3 thousand du
Existing cropping pattern:	
Olives	37%
Vegetables	25%
Fruit Trees and mixed cropping	18%
Fodder crops	20%
Irrigated area in 1987 mapped from RS	14.0 thousand du
Irrigated area in 2002 mapped from RS	57.6 thousand du
Irrigation efficiency	Low (<65%)
Losses (Conveyance, Application, Storage)	High
# of detected open reservoirs (Irrigation pools)	239

Amman-Zarqa Basin

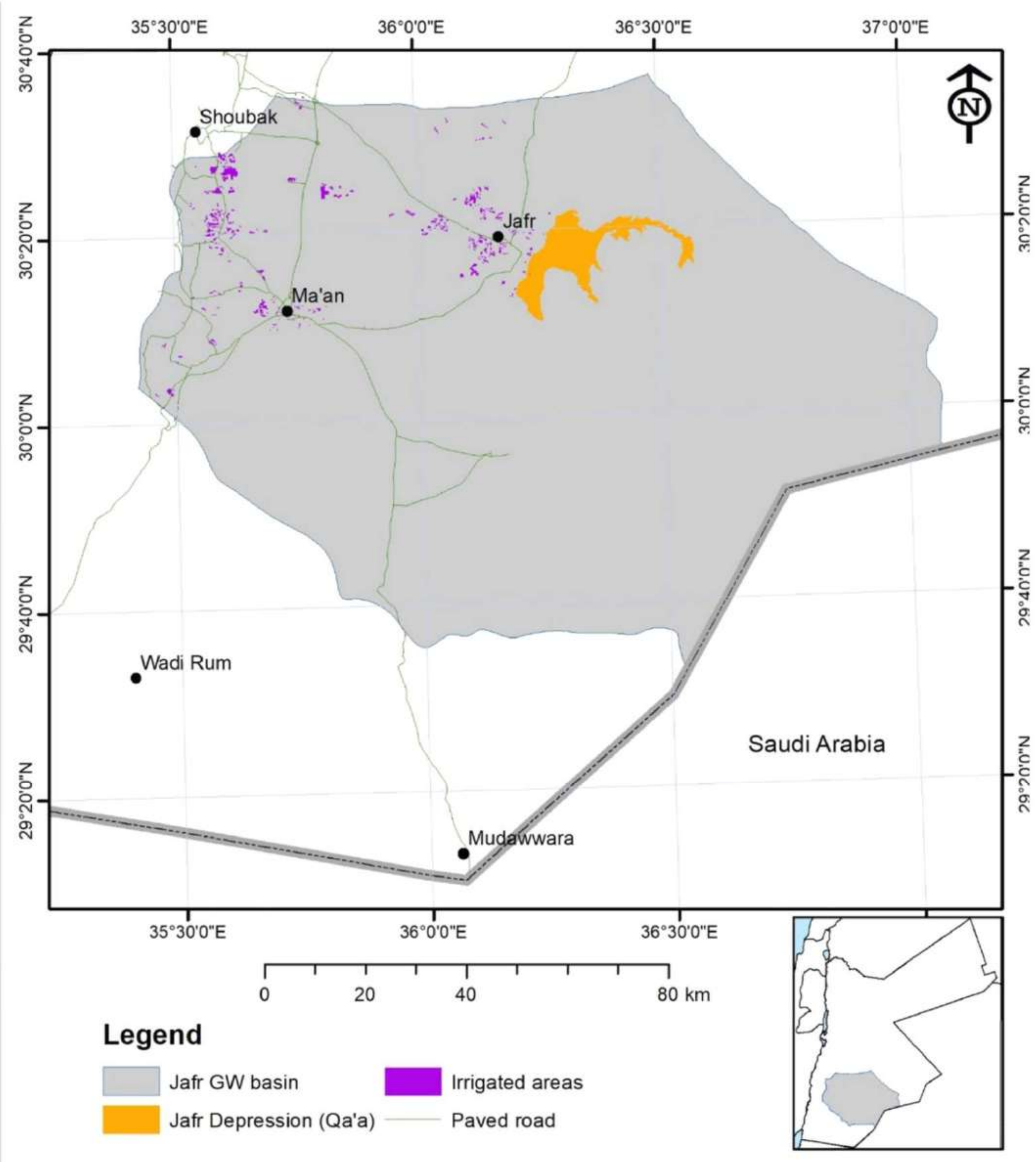


Abstraction -Basin level recorded by MWI (2017)	**75 MCM**
Abstraction (Basin level) calculated from RS study	105 MCM from GW
Possible water savings (MCM) in the hotspots:	18-25 MCM
By water auditing and monitoring	18 MCM
By improving irrigation efficiency 10%	7 MCM
- Irrigated area in 2017 mapped from RS **- GIWR**	219 thousand du 123 MCM
Existing cropping pattern: **Vegetables** **Fruit Trees** **Olives** **Fodder crops** **Mixed cropping patterns**	 33% 28% 28% 6% 5%
- Irrigated area in 1987 mapped from RS **- GIWR**	50 thousand du 28 MCM
- Irrigated area in 2002 mapped from RS **- GIWR**	93 thousand du 52 MCM
Irrigation efficiency	Low (60%)
Losses (Conveyance, Application)	Medium-High



Dead Sea Basin

Abstraction -Basin level recorded by MWI (2017)	30.2 MCM
Abstraction (Basin level) calculated from RS study	45.3 MCM
Possible water savings (MCM) at the level of basin	10.0-14.0
Possible water savings (MCM) in the hotspots:	10.0
By water auditing and monitoring	7.5
By improving irrigation efficiency	2.5
- Irrigated area in 2017 mapped from RS - GIWR	124 thousand du 45.3 MCM
Existing cropping pattern: Vegetables Olives Fruit Trees Mixed crops Fodder crops	 50% 20% 9% 14% 7%
- Irrigated area in 1987 mapped from RS - GIWR	40 thousand du 15 MCM
- Irrigated area in 2002 mapped from RS - GIWR	67 thousand du 24 MCM
Irrigation efficiency	Low (60%)
Losses (Conveyance & Application)	Medium-High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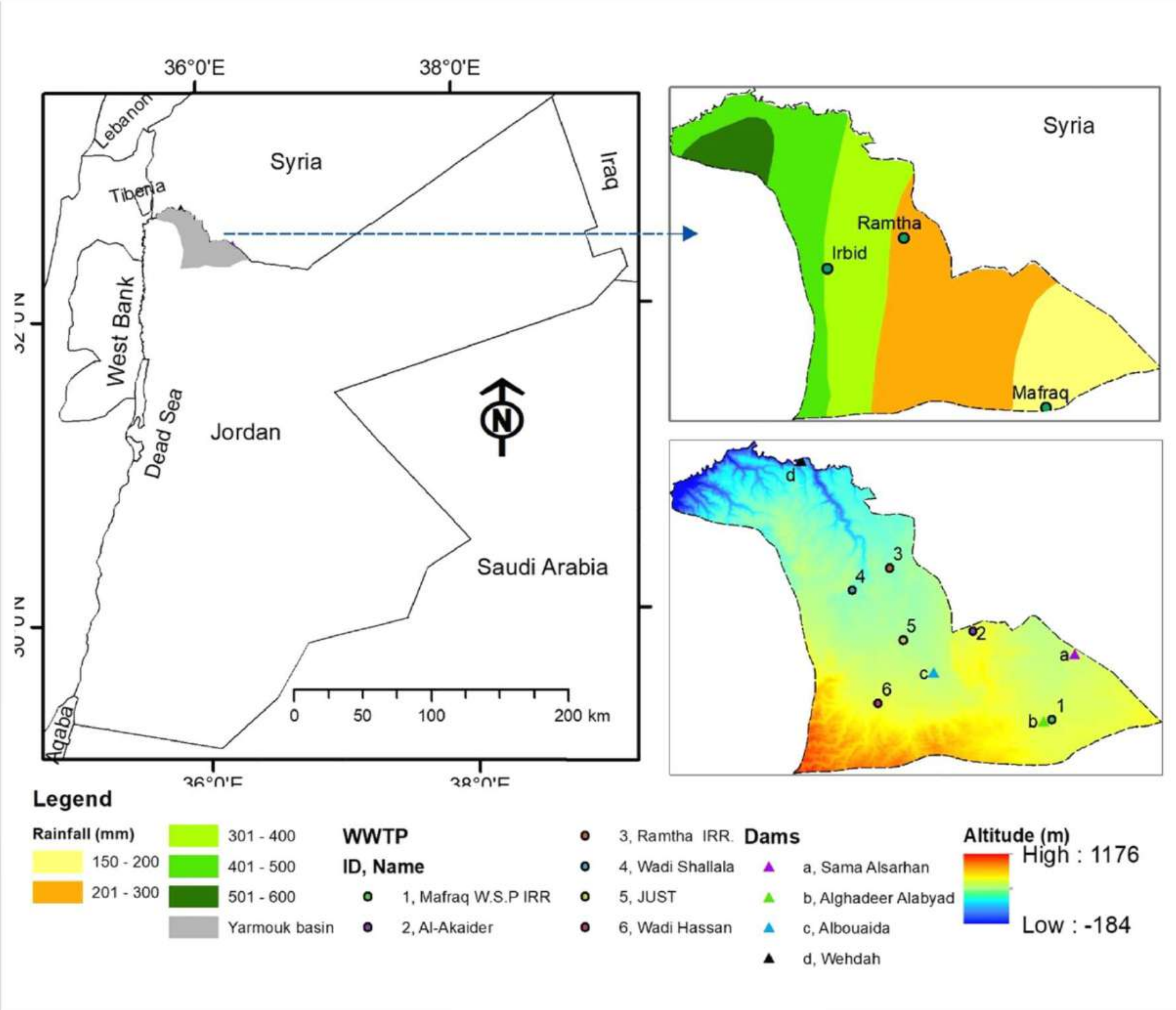
29°40'0"N
29°20'0"N
Shoubak
Jafr
Ma'an
Wadi Rum
Saudi Arabia
Mudawwara
0
20
40
80 km
Legend
Jafr GW basin
Irrigated areas
Jafr Depression (Qa'a)
Paved road

Jafer Basin

Abstraction -Basin level recorded by MWI (2017)	**13.5 MCM**
Abstraction (Basin level) calculated from RS study	29.3 MCM
Possible water savings (MCM) in the hotspots:	9.5-11.4 MCM
By water auditing and monitoring	9.5 MCM
By improving irrigation efficiency	1.9 MCM
Existing cropping pattern: **Vegetables** **Fruit Trees** **Olives** **Mixed cropping patterns** **Fodder crops**	 57% 17% 12% 7% 7%
- Irrigated area in 1987 mapped from RS **- GIWR**	9.4 thousand du 4.8 MCM
- Irrigated area in 2002 mapped from RS **- GIWR**	22.6 thousand du 11.3 MCM
Irrigation efficiency	Low (65%)
Losses (Conveyance, Application)	Medium-High



Yarmouk Basin

Results of mapping were utilized to assess groundwater abstraction recorded by the Water Authority of Jordan (WAJ). According to WAJ records, the total groundwater abstraction in Yarmouk basin was 38.7 MCM for the year 2017. Remote sensing estimates showed that GIWR could reach 48.2 MCM, which would indicate that 9.5 MCM were not recorded by WAJ, assuming that the overall irrigation efficiency would not go below 50%.

PROPOSED GROUNDWATER MANAGEMENT INTERVENTIONS FOR THE AGRICULTURAL SECTOR

Close the Unlicensed Agricultural Wells

Improve Water Auditing by Utilizing Remote Sensing

Improve the Implemented Irrigation Methods

Changing Cropping Patterns


Thank you