

**A Decision Support System (DSS)
for
Integrated Water Resources Management**



**WEAP-
MODFLOW
DSS**



Outline

- Introduction
- WEAP
- Software developments
- Pilot study Zabadani
- Examples and conclusions

Technical Cooperation Project

Management, Protection and Sustainable Use of Groundwater and Soil Resources in the Arab Region

The Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD),
Federal Institute for Geosciences and Natural Resources (BGR)

Aim of the project

Development and application of a
user-friendly
efficient
inexpensive
easily sharable
water planning and management tool
and its
dissemination and institutionalisation
towards a
better integrated water resources management
in the Middle East (and beyond)

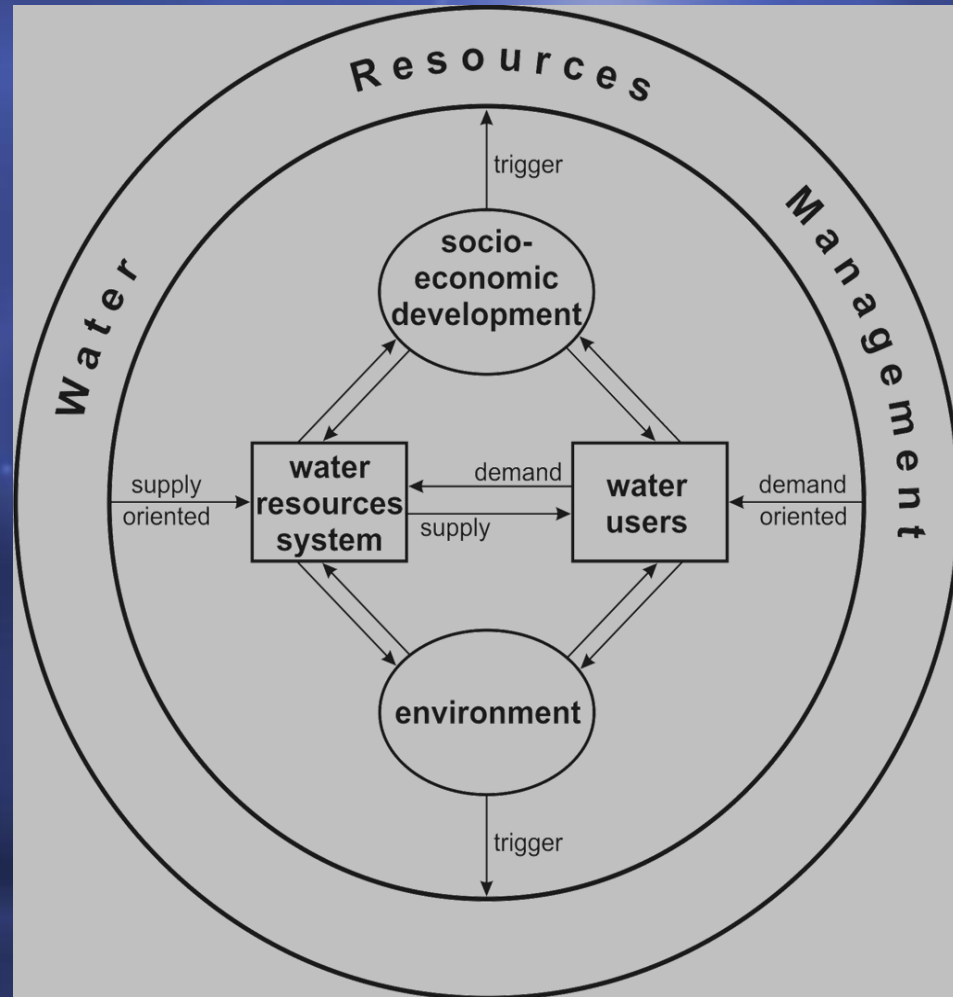
Decision Support System (DSS)

- Support for decision makers in badly structured decision situations
- Interactive method for solving problems
- Decisions are not automated
- Expert knowledge, experiences and judgments of decision makers have to be incorporated
- No general and all-encompassing instrument for solving problems
It generates no solution independently
and solves problems not completely

Basic structures of a DSS:

- Data component, databank
- Model-/method-component, database of methods
- Dialog component

Decision Support System (DSS) for Integrated Water Resources Management (IWRM)



Tasks of a DSS for IWRM

- Analysis of the present water management in a complex interacting system
- Evaluation of future scenarios, taking into account
 - change of water demand and resources (climate change, socio-economic development, ...)
 - different water management options

[Koudstaal et al. 1991]

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The early beginning... selection of a suitable DSS

- easy to use
- free of charge
- catchment scale





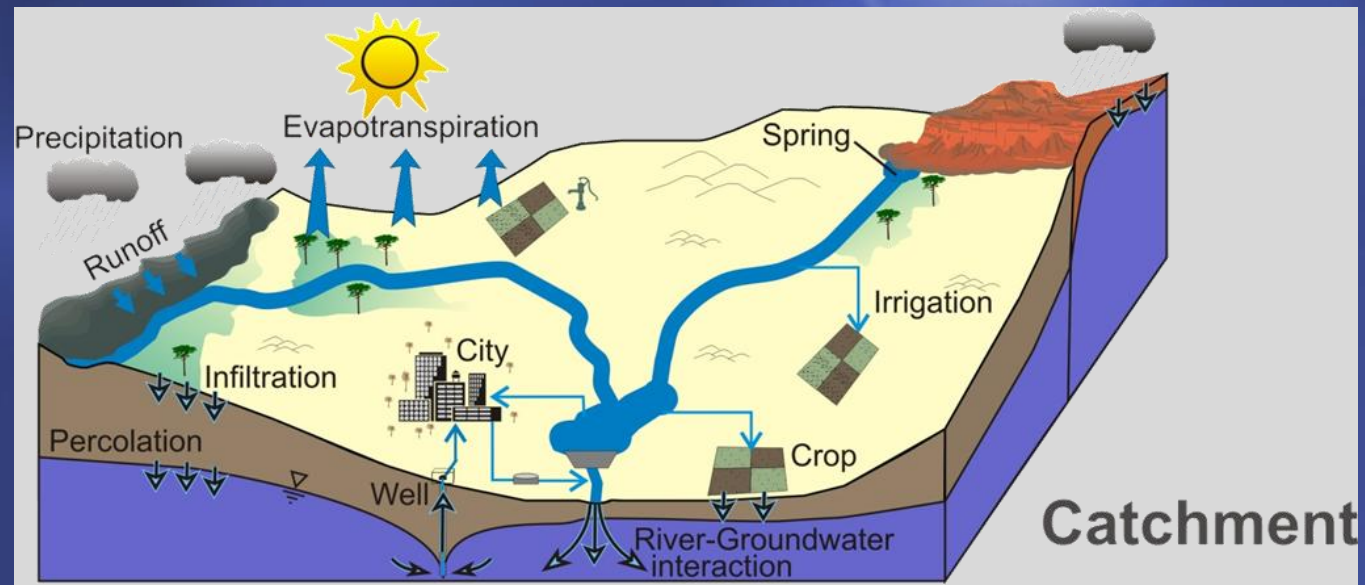
Water Evaluation And Planning System www.weap21.org as a Decision Support System

- Integrated watershed hydrology and water planning model
- GIS-based, graphical drag & drop interface.
- Physical simulation of water demands and supplies.
- Additional simulation modeling: user-created variables, modeling equations and links to other models.
- Scenario management capabilities.
- Watershed hydrology, water quality and financial modules
- The data structure and level of detail may be easily customized to meet the requirements of a particular analysis and to reflect the limits imposed when data are limited.
- Developed by Boston Center of the Stockholm Environment Institute, www.sei-us.org

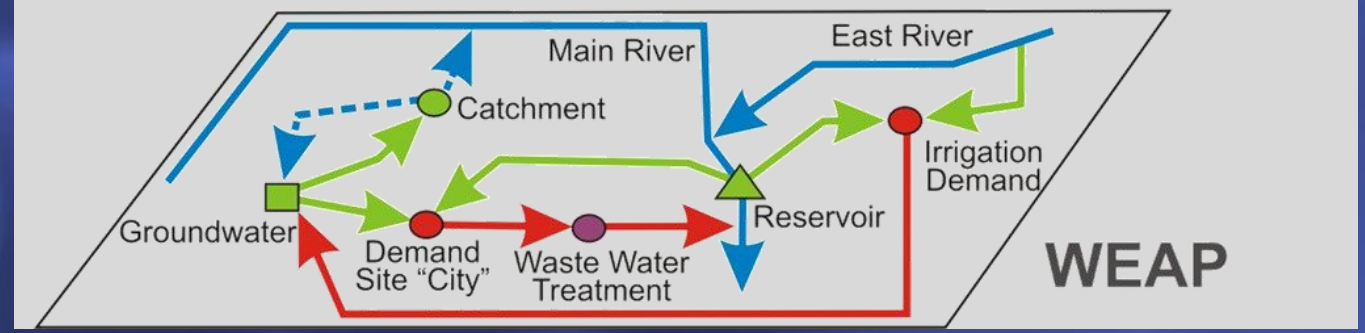


WATER EVALUATION & PLANNING SYSTEM - www.weap21.org

The base is the water balance in a catchment



All processes are modeled by nodes and links

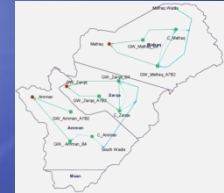


WEAP DSS for IWRM

- standard procedure -

System Definition

Configuration of the hydraulic system



Scenarios

Demographic and economic activity

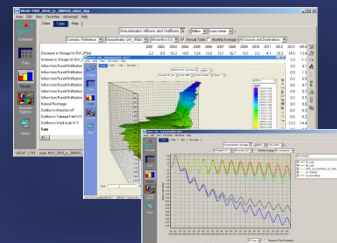
Climate change

Water management

- Analysis of the future water balance
 - Consideration of uncertainties, e.g. climate change, population growth
 - Evaluating of water management activities, e.g. new pipelines, new irrigation techniques
- Sensitivity studies

Evaluation

Charts, tables, maps



- *Change of groundwater storage*
- *Change in stream flow*
- *Demand coverage*
- *Costs, . . .*

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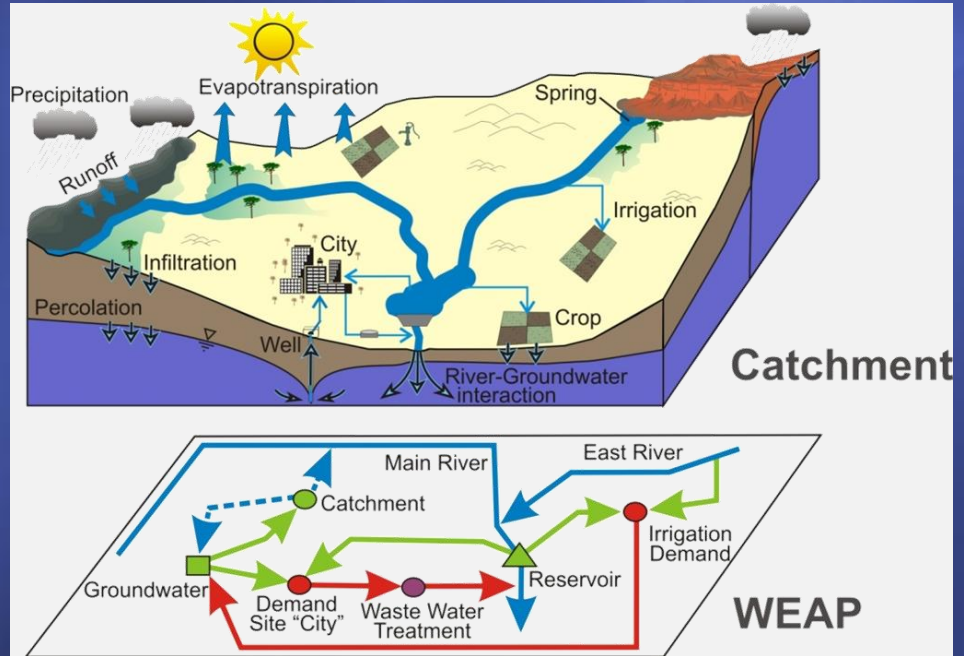
WEAP-MODFLOW Linkage

Groundwater is the main water resource in the Arab Region

Detailed information about groundwater drawdowns and flows are of special interest



Groundwater flow model is needed!



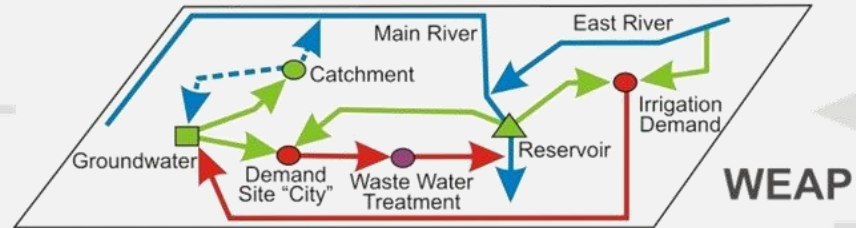
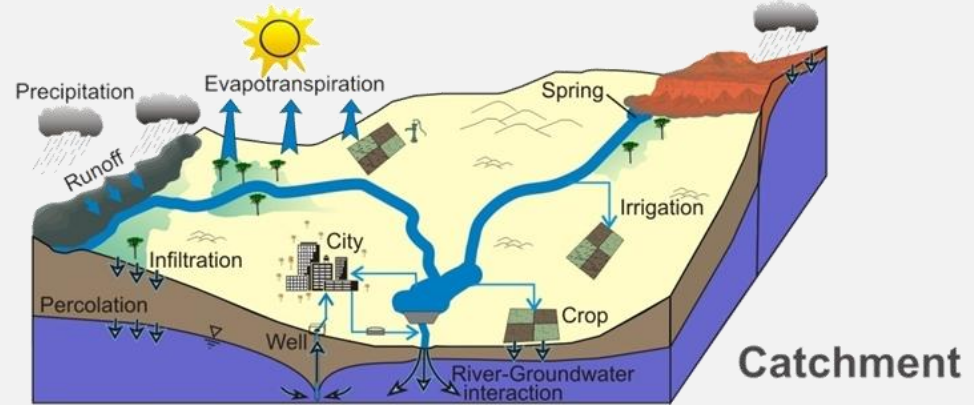
WEAP-MODFLOW Linkage

Groundwater is the main water resource in the Arab Region

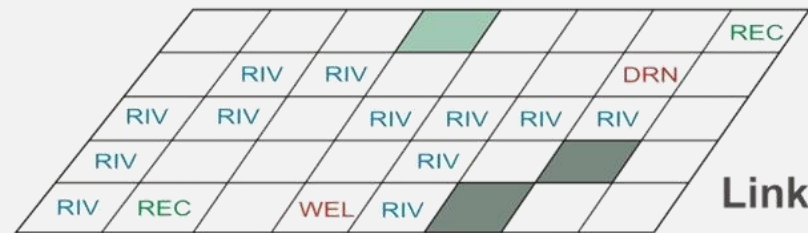
Detailed information about groundwater drawdowns and flows are of special interest



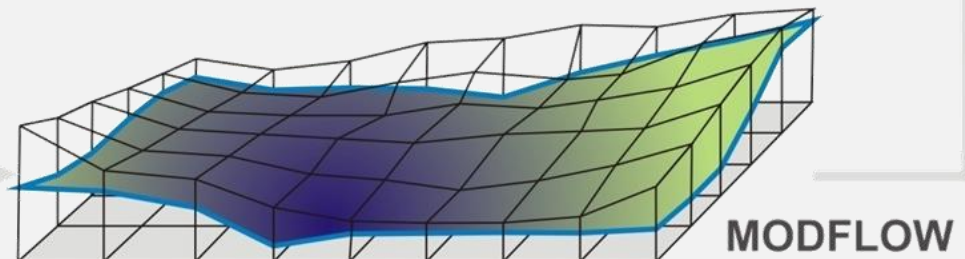
Groundwater flow model is needed!



GW Recharge
Abstraction Rate
River Stage



Hydraulic Head
Storage Volume
Spring Discharge
Groundwater Flow

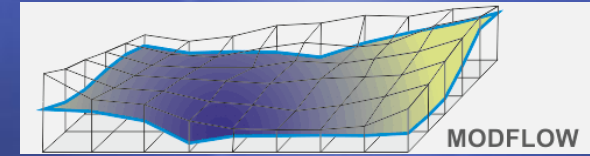


WEAP - DSS - Enhancements

Initiated by the ACSAD-BGR project

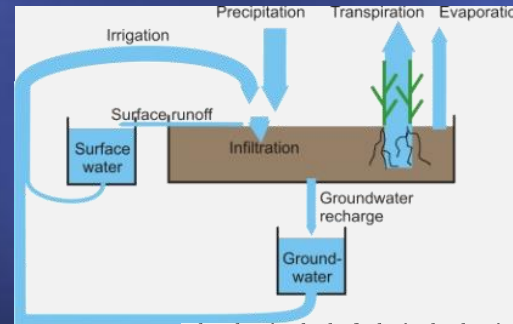
MODFLOW

Integration of a 3d groundwater flow model



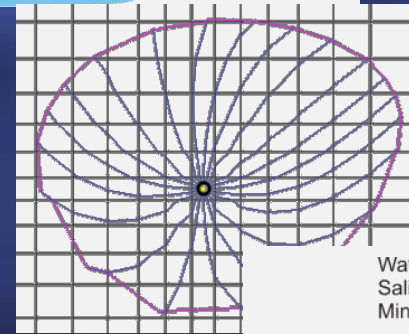
MABIA

Enhanced soil water balance model
(integrated in WEAP)



MODPATH

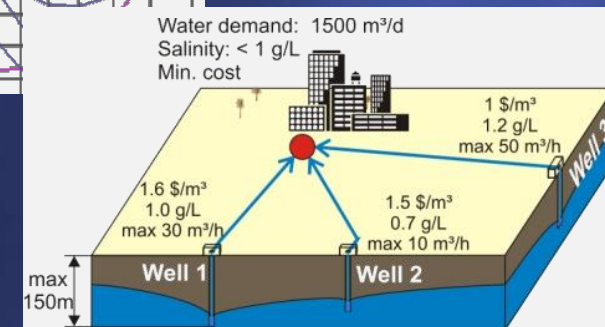
3d particle tracking model
(integrated in WEAP)



All_WATER_gw Optimization

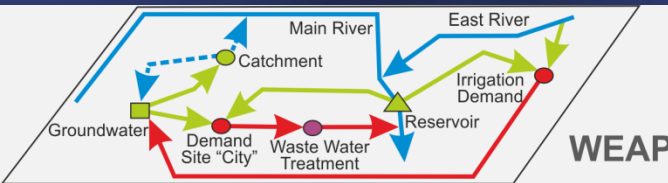
Optimization of abstraction rates
and pumping allocation

(developed by Issam Nouri, INAT, Tunisia)

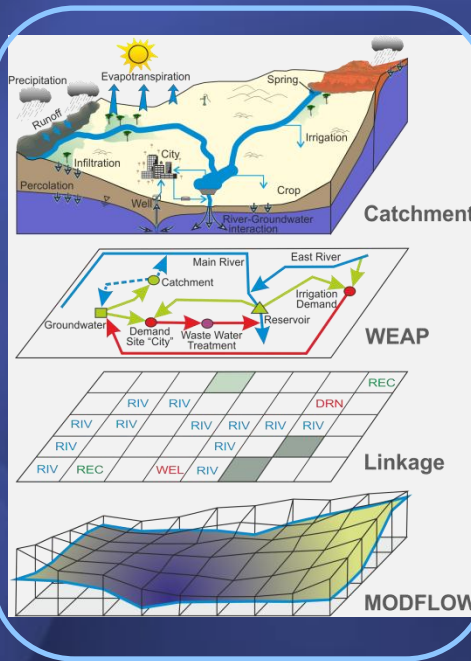


Software Concept

Software needed to setup a WEAP-MODFLOW DSS - so far



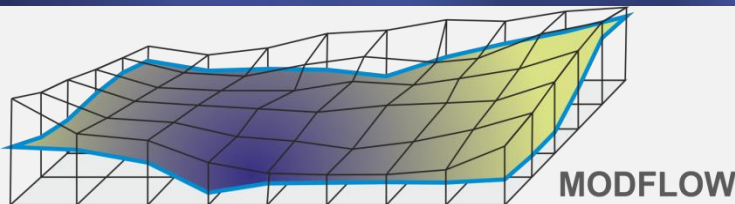
- WEAP
- Cropwat



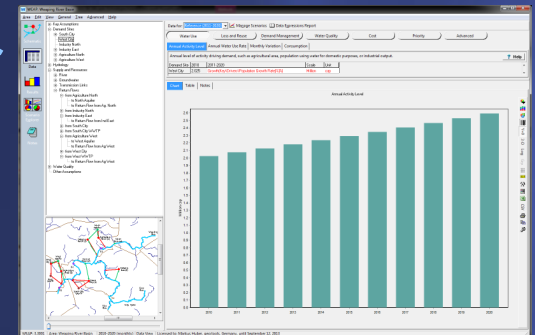
Linkage

| | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|--|--|-----|
| | | | | | | | | | REC |
| | RIV | RIV | | | | | | | DRN |
| RIV | RIV | | RIV | RIV | RIV | RIV | | | |
| RIV | | | | RIV | | | | | |
| RIV | REC | | WEL | RIV | | | | | |

- MODFLOW2WEAP
- ArcGIS
- Access
- WEAP



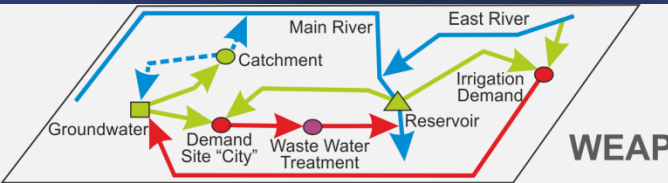
- GMS / PMWIN
- MODFLOW / MODPATH



- Excel
- Text Editors

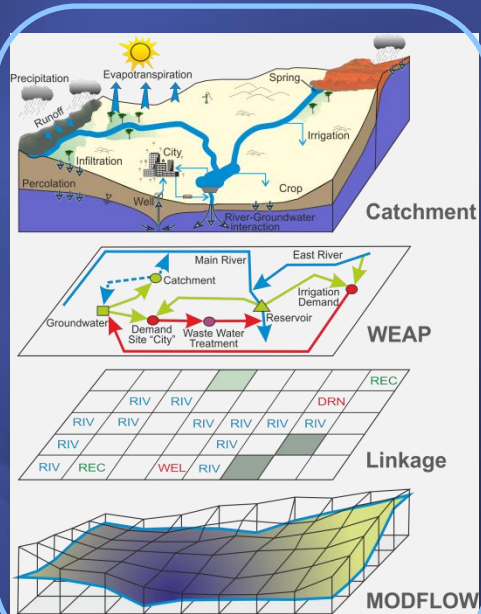
Software Concept

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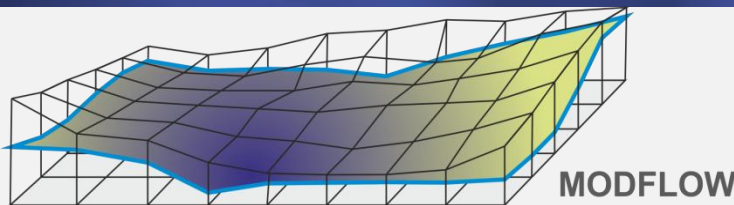
- WEAP
- ~~Cropwat~~

Substituted by MABIA;
integrated in WEAP



| | | | | | | | | | |
|-----|-----|-----|-----|-----|-----|-----|--|--|-----|
| | | | | | | | | | REC |
| | RIV | RIV | | | | | | | DRN |
| RIV | RIV | | RIV | RIV | RIV | RIV | | | |
| RIV | | | | RIV | | | | | |
| RIV | REC | | WEL | RIV | | | | | |

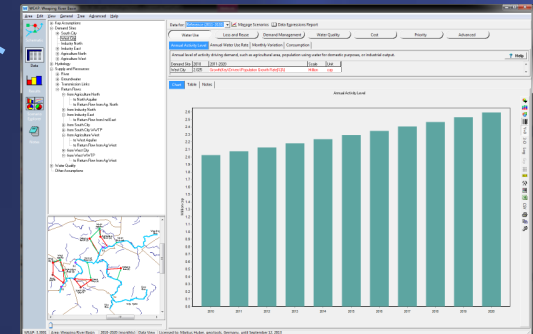
- ~~MODFLOW2WEA~~
- ~~P~~
- ~~ARC GIS~~
- ~~Access~~
- WEAP



- ~~GMS / PMWIN~~
- ~~MODFLOW / MODPATH~~ ← integrated in WEAP

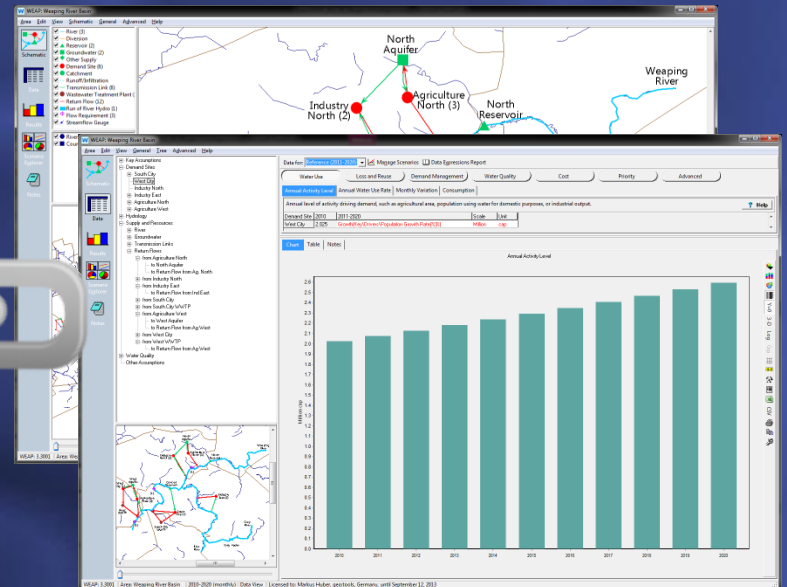
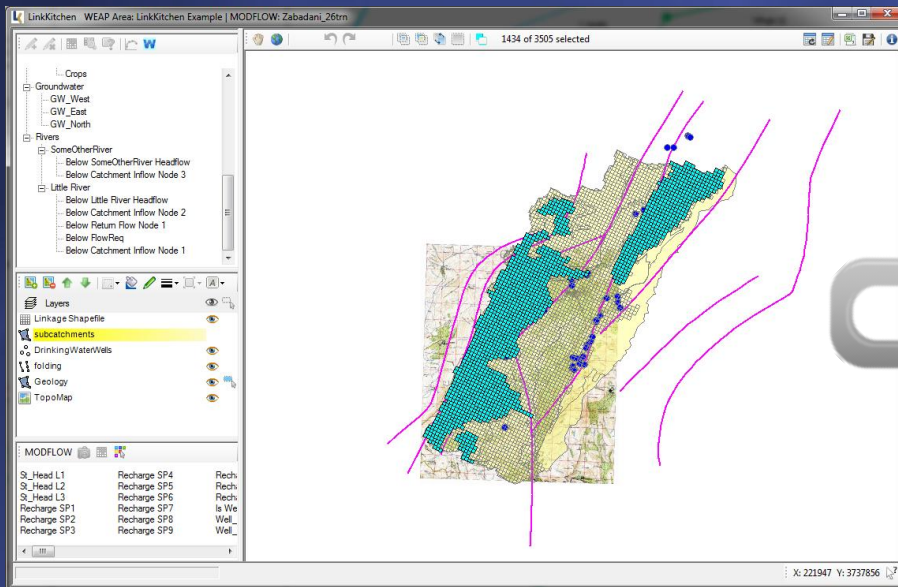
← No topic in workshops,

- ~~Excel~~
- ~~Text Editors~~



LinkKitchen

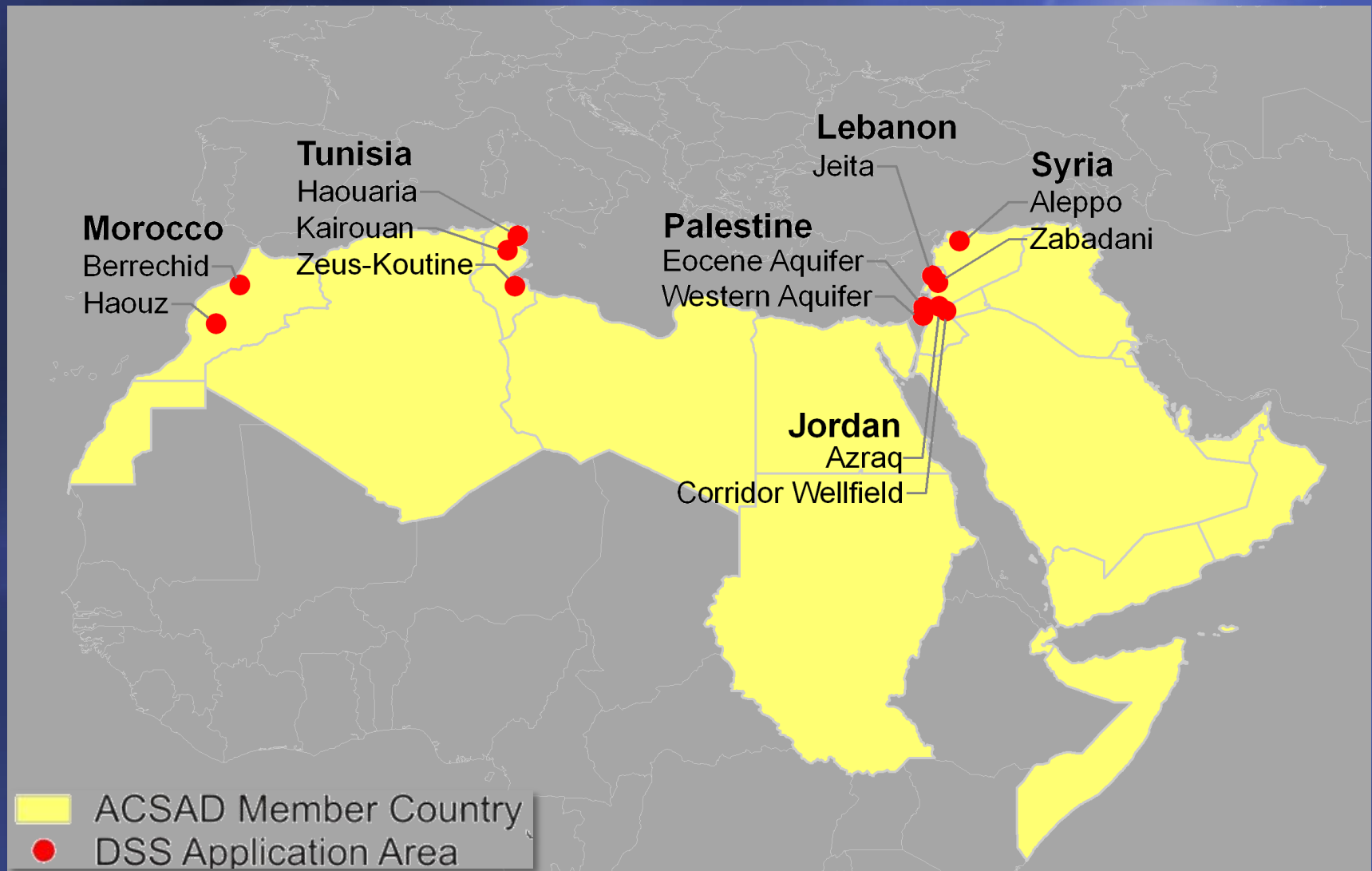
- GIS-comparable user interface – no GIS software/license required
- Optimized for the setup of the Linkage File – no more, no less
- Intuitive handling
- No more typing errors
- Comprehensive data-file management – no more orphaned files
- Automated, direct data transfer from/to WEAP



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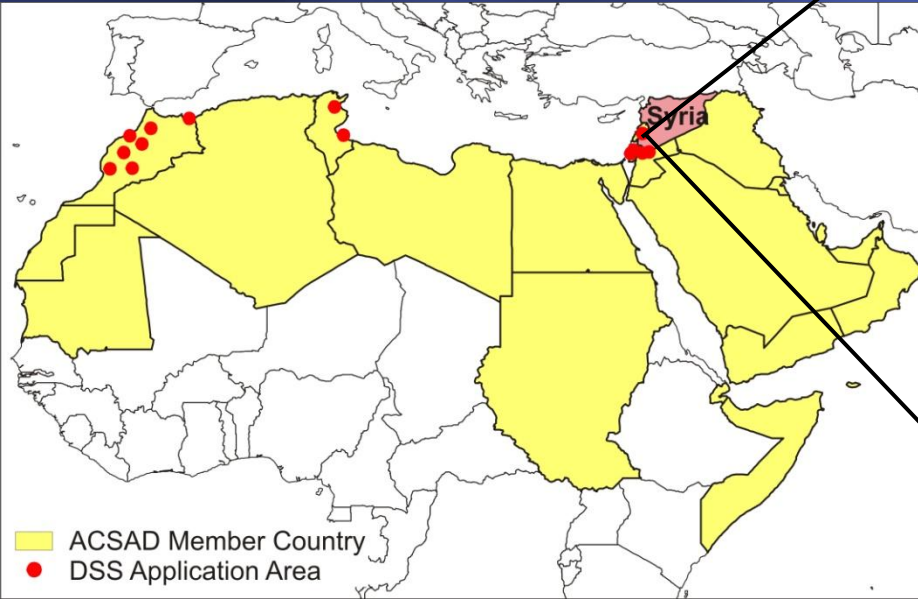
WEAP – MODFLOW applications in the Arab Region encouraged by the project



Pilot Study

Zabadani Basin Syria

- Northwest of Damascus
- Area 165 km²





Agriculture

Drinking water
Damascus

Water
Conflict



Drinking water
local



Tourism



INPUT DATA

Hydraulic System

rivers, canals, transmissions, runoff

Climate

temperature
precipitation
cloudiness

Soil

types
layers
water capacities

Landuse

crop type
irrigation

Demands

domestic
industrial
demography

Resources

river head flow
hydrogeology
inflows

DSS

WEAP

schematic

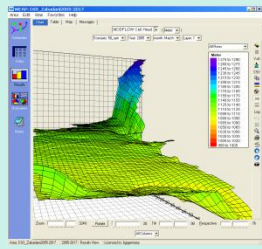
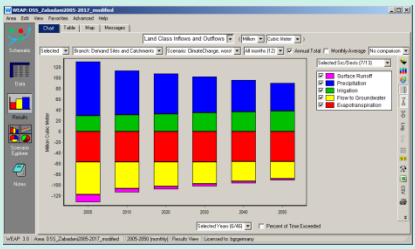
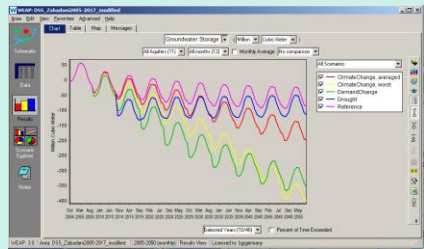
internal models

linkage

MODFLOW

FD groundwater flow model

RESULTS



Water balance, flows, unmet demand, irrigation demand, water use, water storage, groundwater head

THEMATIC MAPS:



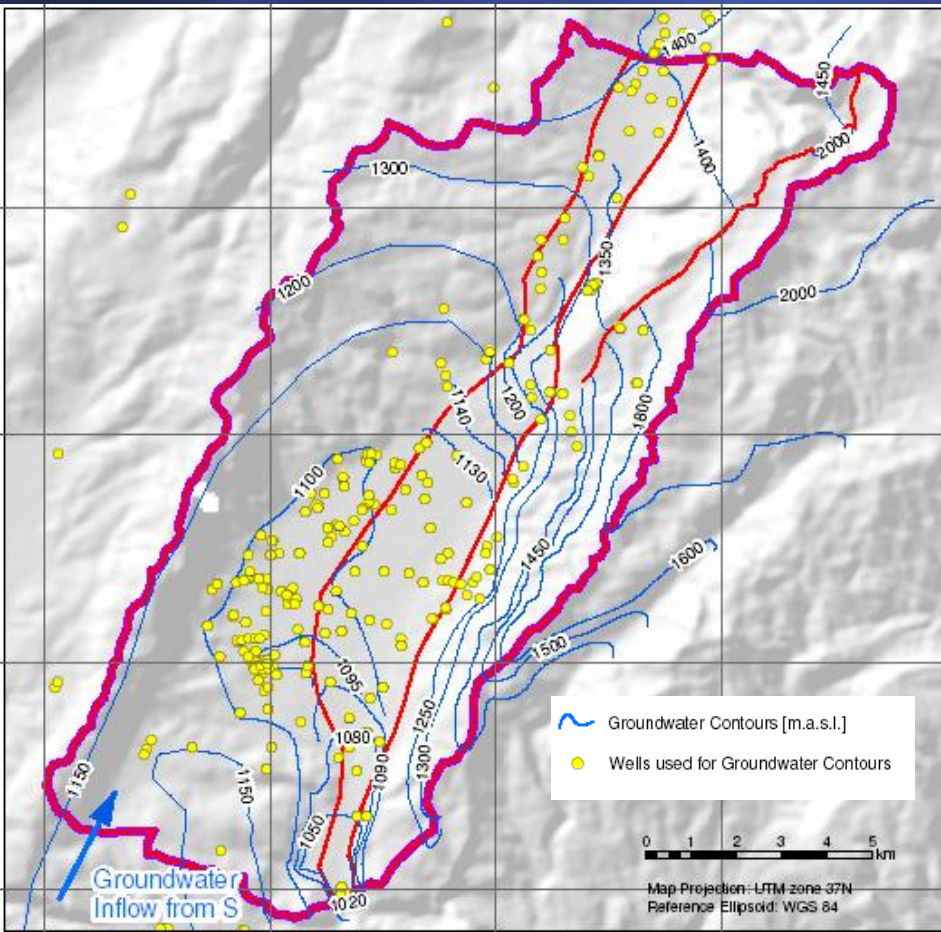
Arab-German Technical Cooperation

Management, Protection and Sustainable Use of Groundwater and Soil Resources

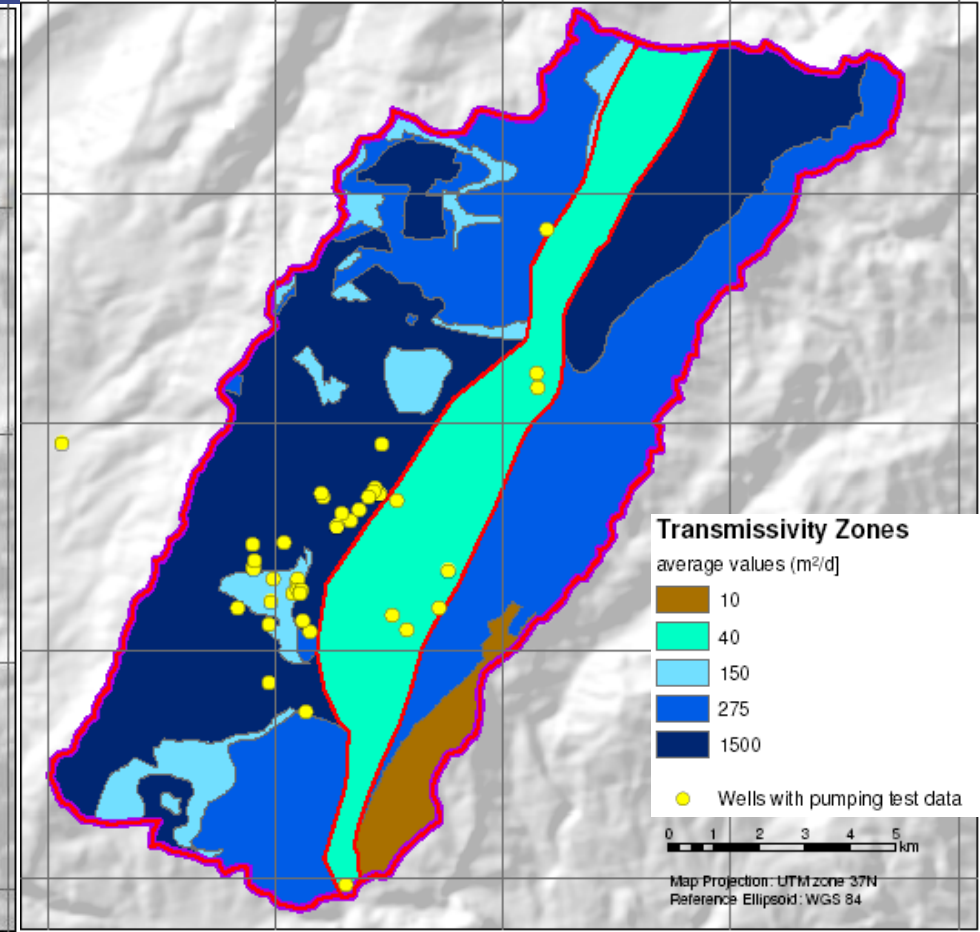


Decision Support System Zabadani Basin

Groundwater Contours

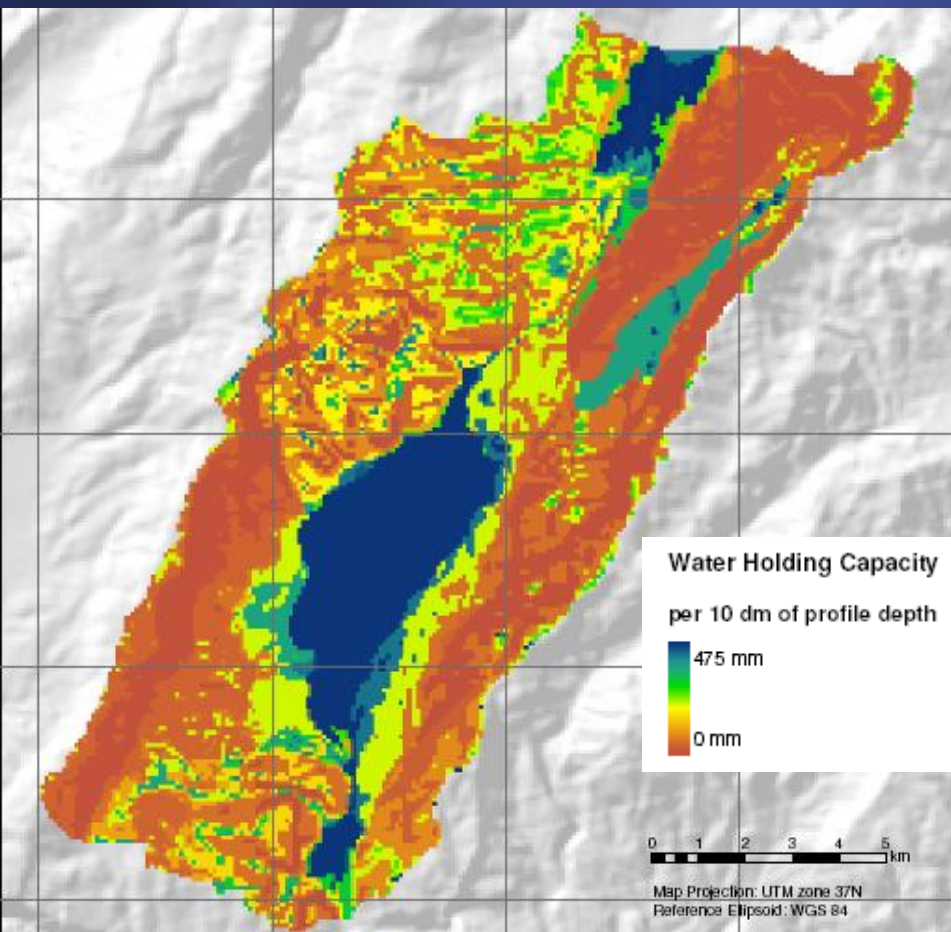


Transmissivity Zones

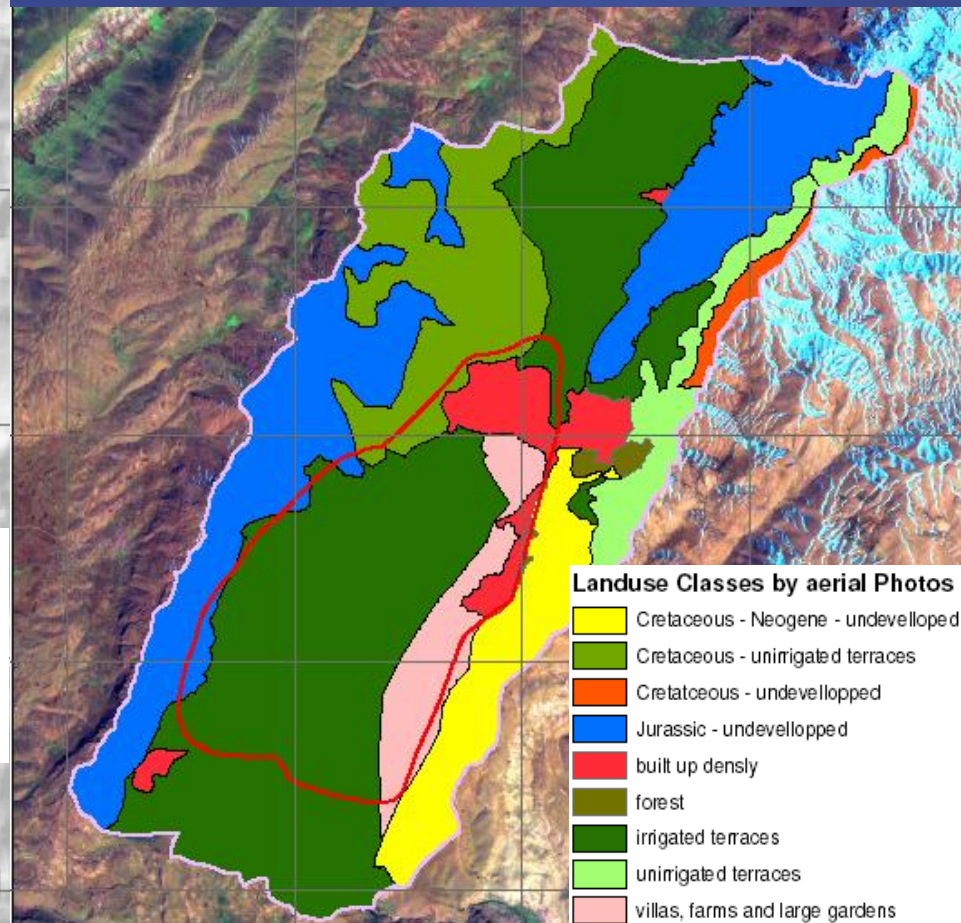


THEMATIC MAPS:

Soil Water Holding Capacity



Landuse Map





Schematic



Data



Results



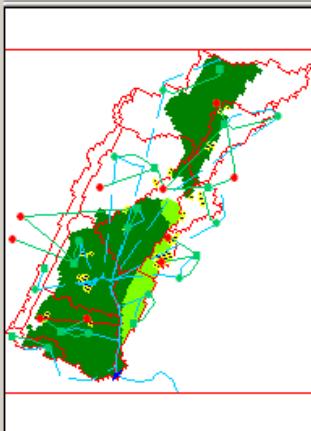
Scenario Explorer



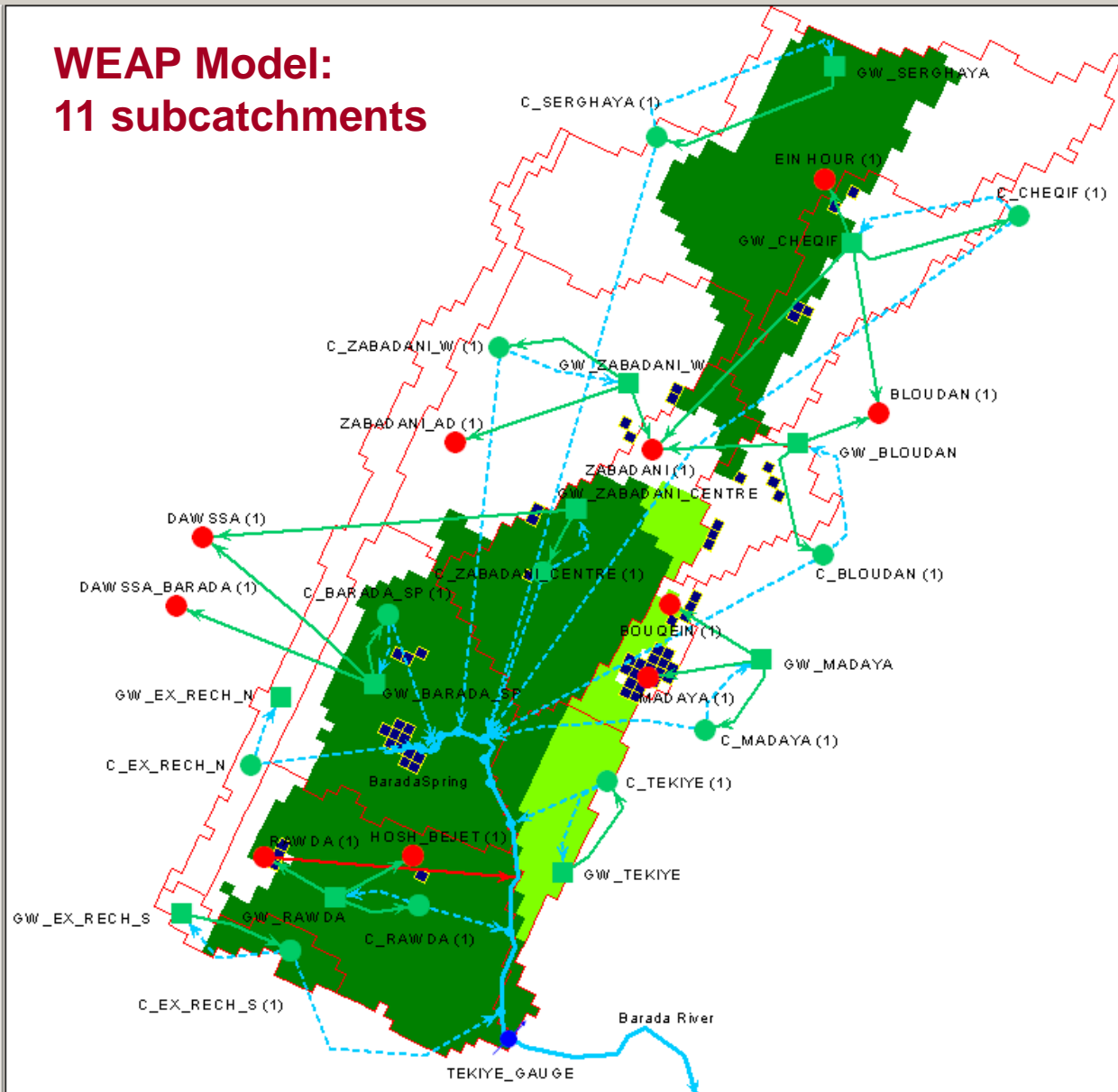
Notes

- River (2)
- Diversion
- Reservoir
- Groundwater (11)
- Other Supply
- Demand Site (10)
- Catchment (11)
- Runoff/Infiltration (22)
- Transmission Link (24)
- Wastewater Treatment Plant
- Return Flow (1)
- Run of River Hydro
- Flow Requirement
- Streamflow Gauge (1)

- 070520_Linkage
- SC_LU
- SC
- MFwell_CELLS
- 070520_Linkage_SC
- 070520_Linkage_SC_LU
- 070520_Linkage
- irrigated_terraces
- farms_gardens_villas



WEAP Model: 11 subcatchments



Scenarios

Planning scenarios 2005 – 2050

O) No change, reference

Precipitation and temperature based on the average of the period 1961-1990

A) Demand change

Increase in water abstraction for domestic use until 2020

B) Drought cycle

Considering 4 consecutive drought years (2011-2014)

C) Climate Change

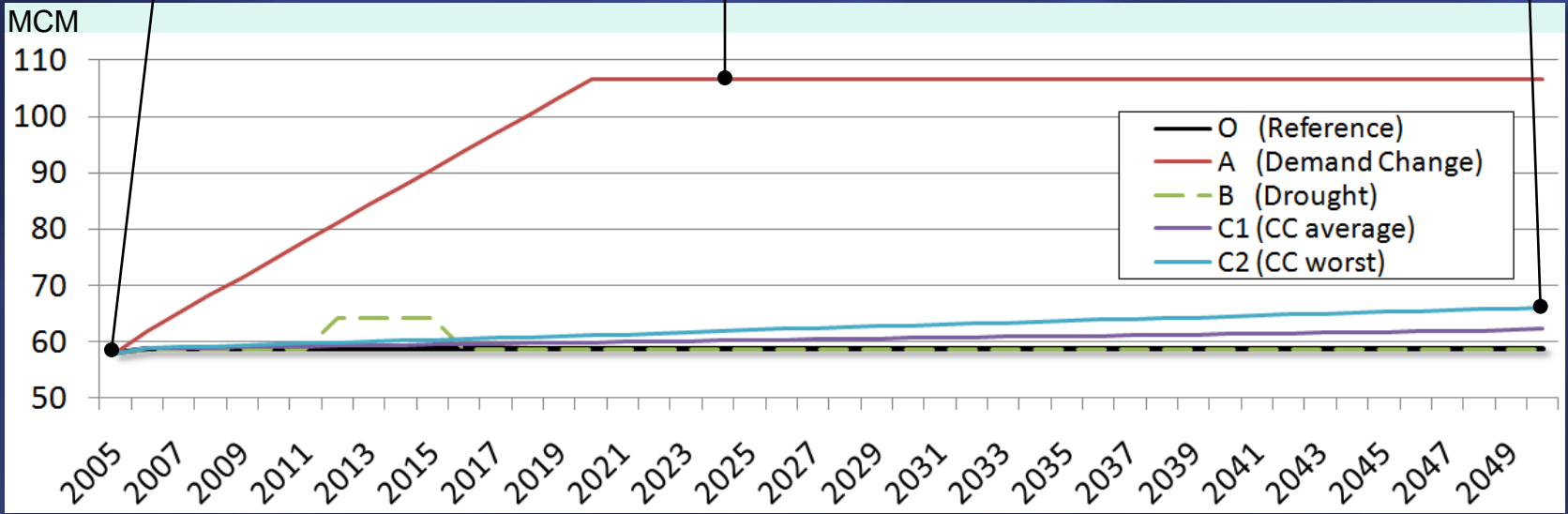
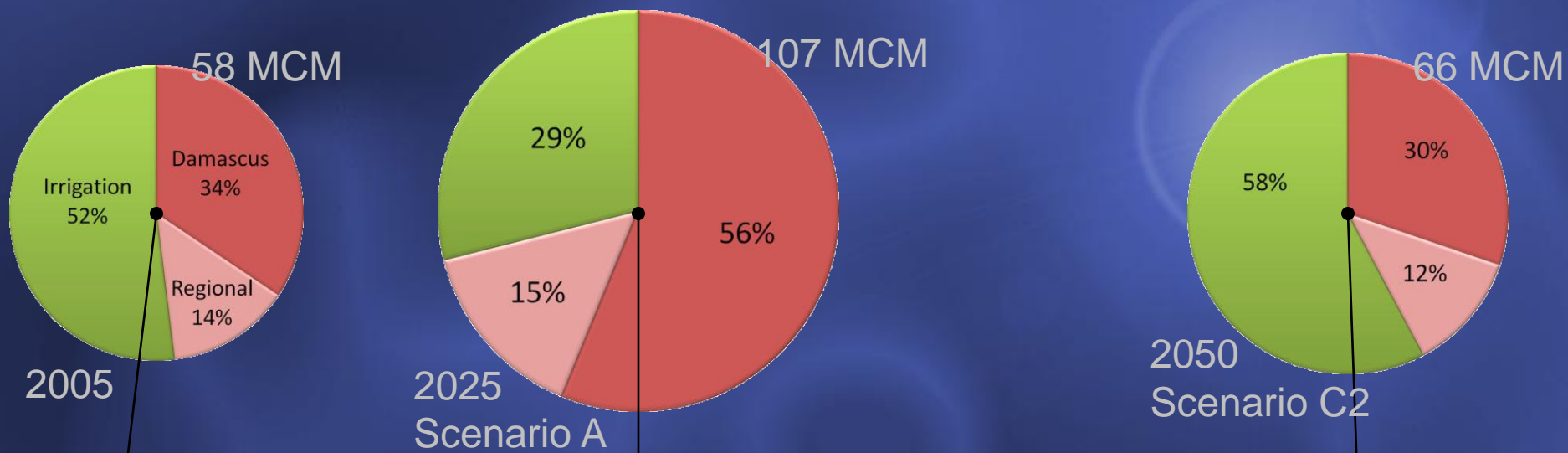
Decrease of precipitation and lateral GW inflow, increase of temperature

IPCC climate scenarios A2, A1B, B1, (16 modeling groups)

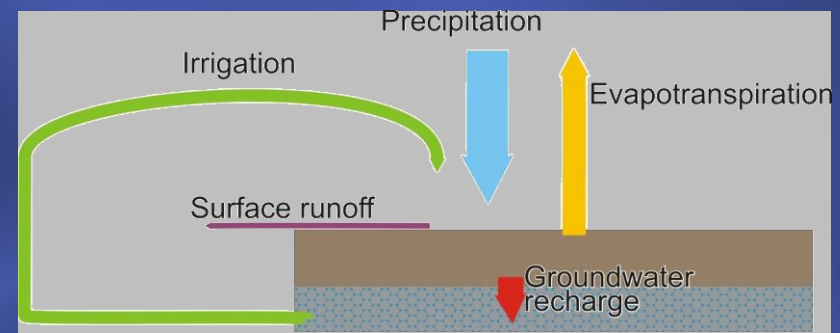
C1) average of all results

C2) worst case

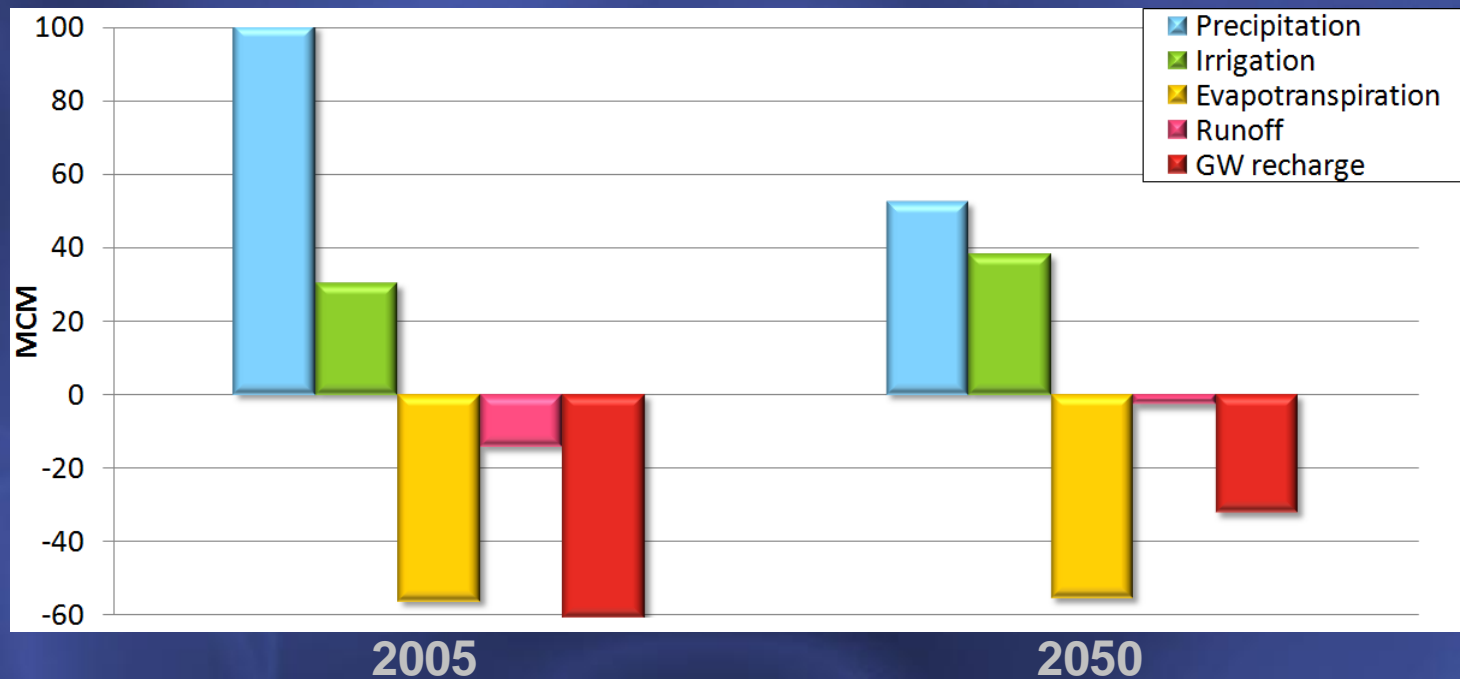
Water Demand and Water Usage



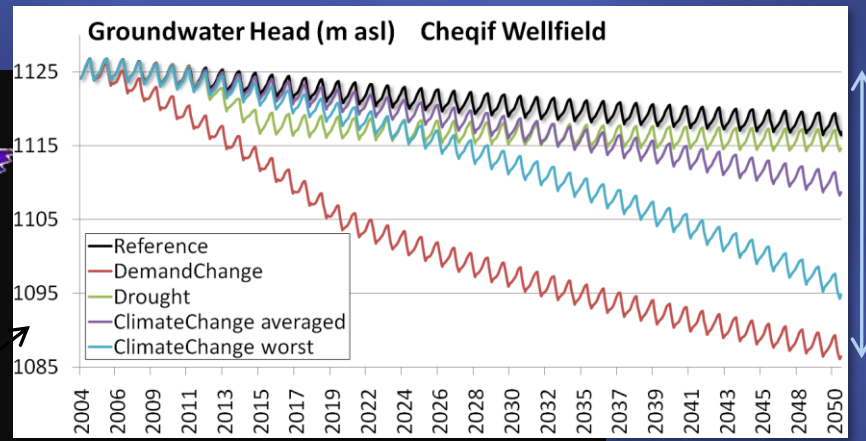
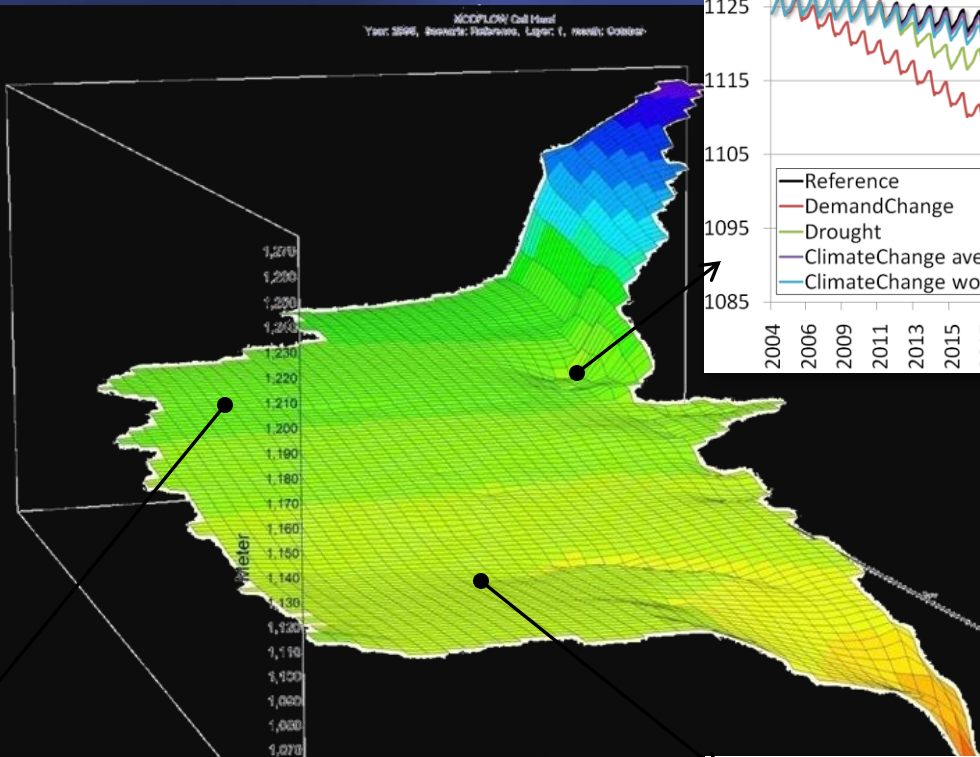
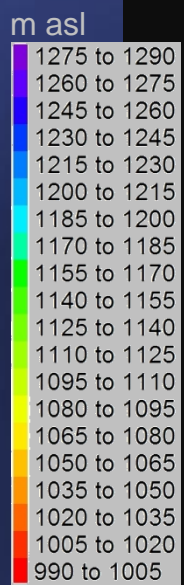
Water Balance



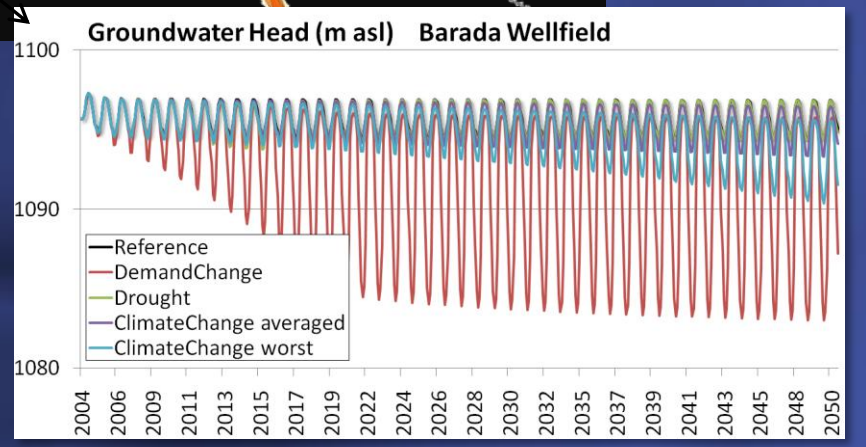
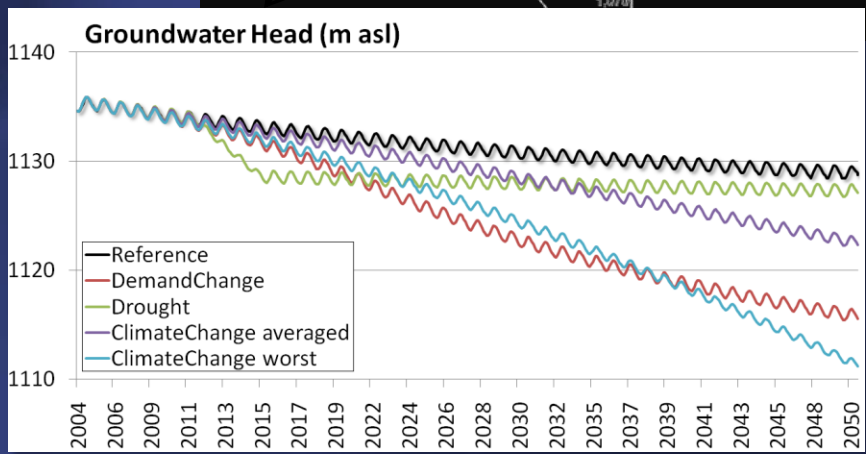
Scenario C2: Climate Change, worst case



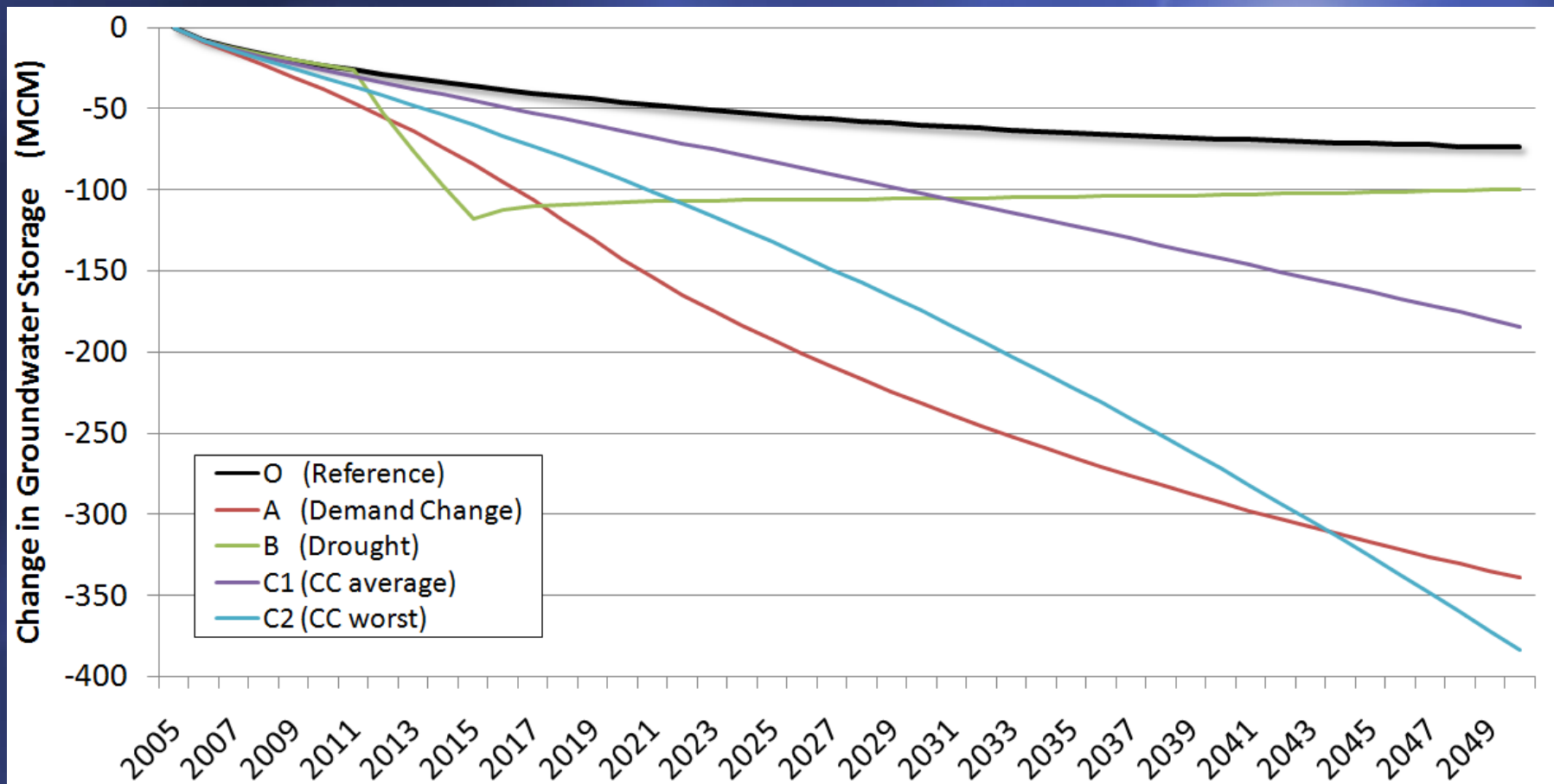
Groundwater Head



decline up to 40 m



Change in Groundwater Storage

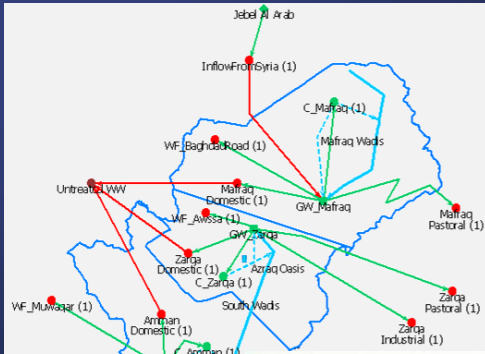


Outline

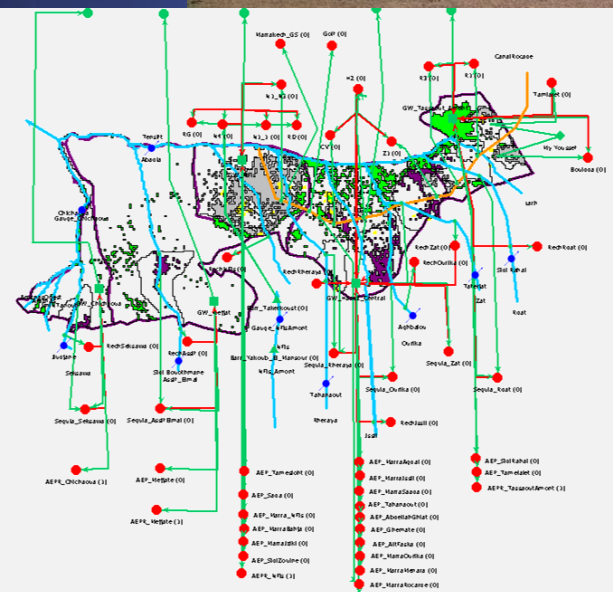
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Examples

Zeuss-Koutine / Tunisia
water quality aspects
decision making process



Azraq / Jordan
used within the
National Water Master Plan



Haous Mejjat / Morocco
local water administration
part of the daily work

Some Conclusions

- Since groundwater is the main resource in the Arab region, a linked approach (groundwater-surface water) is essential
- The WEAP-MODFLOW DSS is a powerful tool to investigate water relevant problems in the framework of IWRM.
- The DSS is a free software for developing countries
- It has successfully been applied in many areas in the Arab region and is used today in several institutions there
- Even if the WEAP-MODFLOW DSS is relatively simple, several weeks are needed to setup a new model together with well educated counterparts and work on the results with decision makers
- A new tool, LinkKitchen, has been developed, which simplifies the WEAP-MODFLOW coupling

Acknowledgements

Many scientists were involved in the Weap-Modflow DSS project since 2004 as planners, managers, software developers and trainers, mainly

ACSAD: A. Droubi, M. Al Sibai, O. Al Shihabi, J. Al Mahamed, W. Seif,

BGR: J. Wolfer, J. Maßmann, K. Schelkes, V. Hennings, M. Gaj, H. Mylius, H.-W. Müller

SEI: J. Sieber, D. Purkey

INAT: I. Nouiri, A. Sahli, M. Jabloun

GeoTools: M. Huber

Many stakeholders, staff members from administrations, institutes, universities and ministries a.s.o. were involved in the process of testing and implementing the software. Their feedback and commitment was very helpful for the improvement of the DSS tool.

Thanks to all of them!

THANK YOU!

www.bgr.bund.de/IWRM-DSS

- reports
- tools
- tutorials

Water - a fundamental necessity of life

