Basin-wide water accounting based on modified SWAT model (SWAT-FARS): an application for the Tashk-Bakhtegan Basin, Iran.

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Introduction (Why this study?)

✓ Analyzing the water resources systems and solving water problems require information from many disciplines, and the physical accounts (describing sources and uses of water) are the most important foundation. This information has to be coherent and harmonized in order to provide an useful integrated picture for the assessment of the problems.

✓ Water accounting frameworks as an useful tool integrate hydrological processes with land use, managed water flows and the services that result from water consumption in river basins and make useful management information for decision makers within the water sector and related to the water sector.

✓ The main aim of this work is to demonstrate the basin wide application of water accounting framework based on the modified version of the SWAT model to produce information on depletion of water resources, storage change, and land and water productivity in a semi arid region in Iran

Objectives

SWAT Soil & Water Assessment Tool

- ✓ **Comprehensive Simulation of water resources and agricultural systems and integrate its results with the water accounting framework.**
- ✓ **SWAT Model and WA+ Water Accounting Framework**

Multi-institutional collaboration

Water accounting system IWMI-WA +

Water accounting is the process of communicating water resources related information and the services generated from consumptive use in a geographical domain, such as a river basin, a country or a land use class; to users such as policy makers, water authorities, managers, etc.

- Developed Version of the IWMI framework
- 8 standard reporting sheet and sets of indicators to help users to better understand the current state of water resources, issues, future challenges and opportunities for improvements in a area.

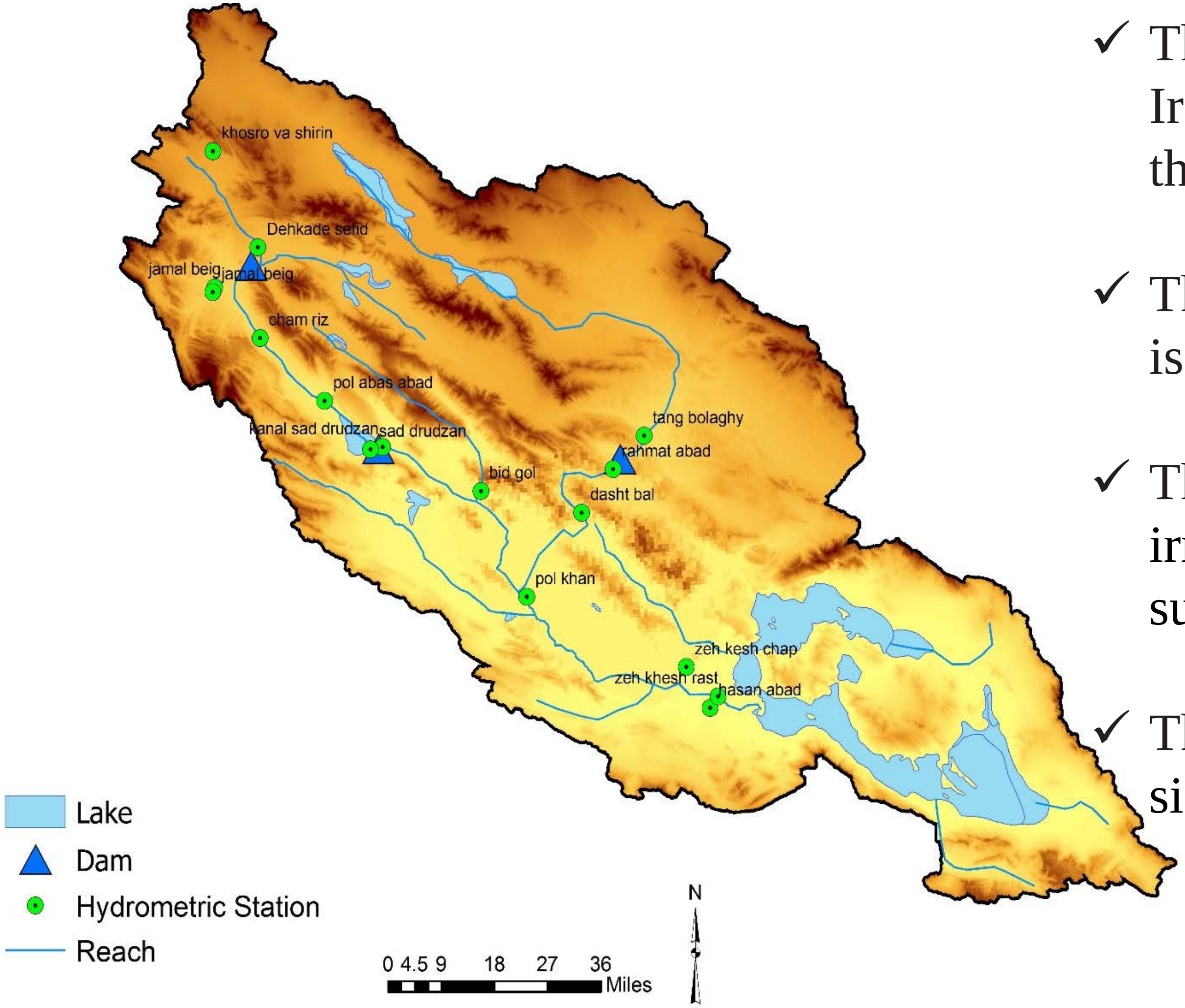
The purpose of WA+ sheets

Water sheets	Purpose
Resource Base	Hydrological, manageable, utilisable flows, water security, sustainability
Evapotranspiration	Beneficial & non-beneficial flows
Productivity	Land and water productivity
Withdrawal	Management, regulations, allocations

It is a multi-institutional effort from international knowledge centers (IWMI, UNESCO-IHE, FAO, and WWAP)

wateraccounting.org

Study Area



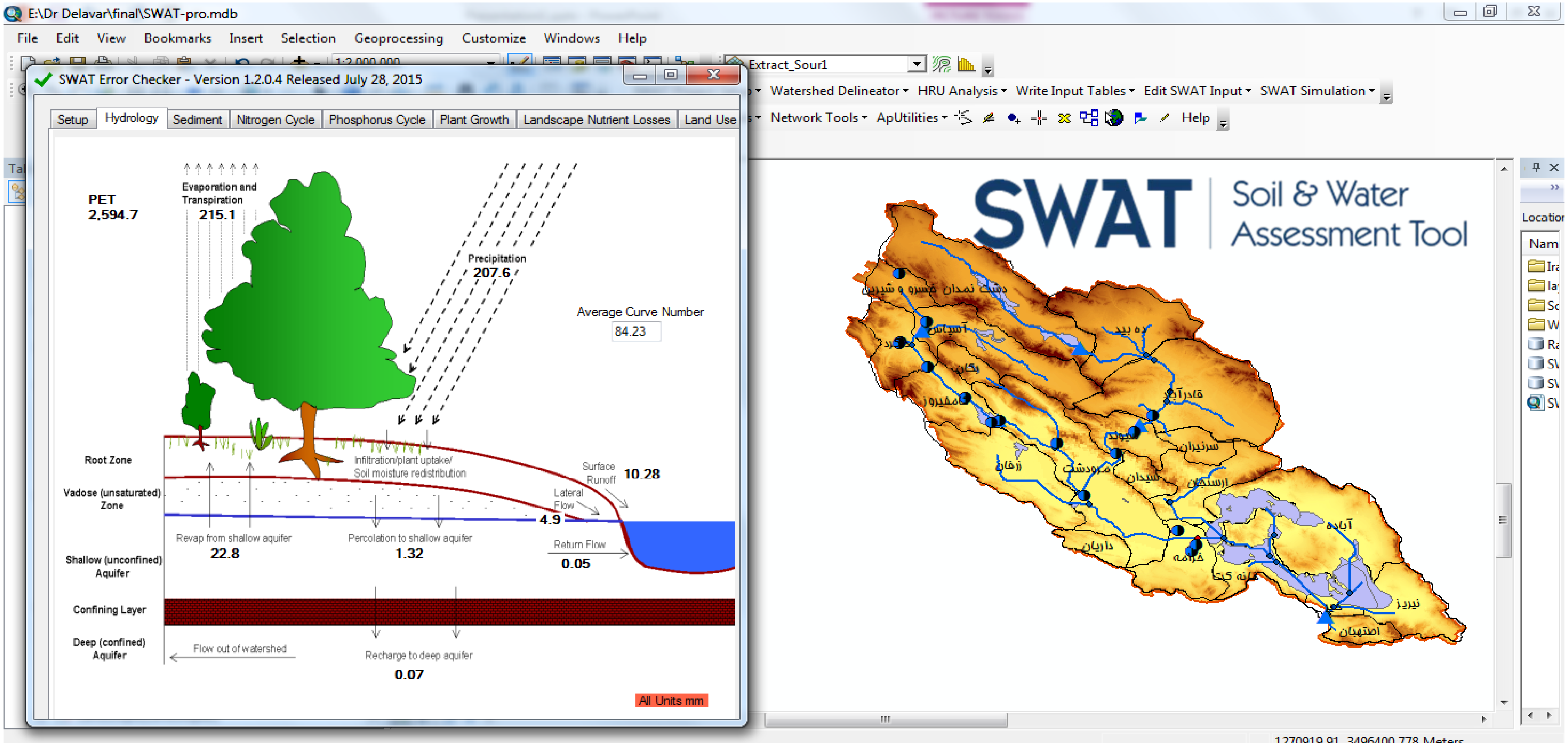
- ✓ The Tashk and Bakhtegan basin is placed in central of the Iran which drains into the Tashk and Bakhtegan Lakes that are now completely dry.

- ✓ The study area is a karsty basin and the region total area is equal to 27000 km2.

- ✓ The basin has a large agricultural areas with intensive irrigation which more than 60% of irrigated agriculture supplies are dependent on groundwater resources.

- ✓ There are three large dams on the basin rivers that significantly reduced water flow into the lakes

Setup the comprehensive simulation model



Spatial Data for SWAT model setup

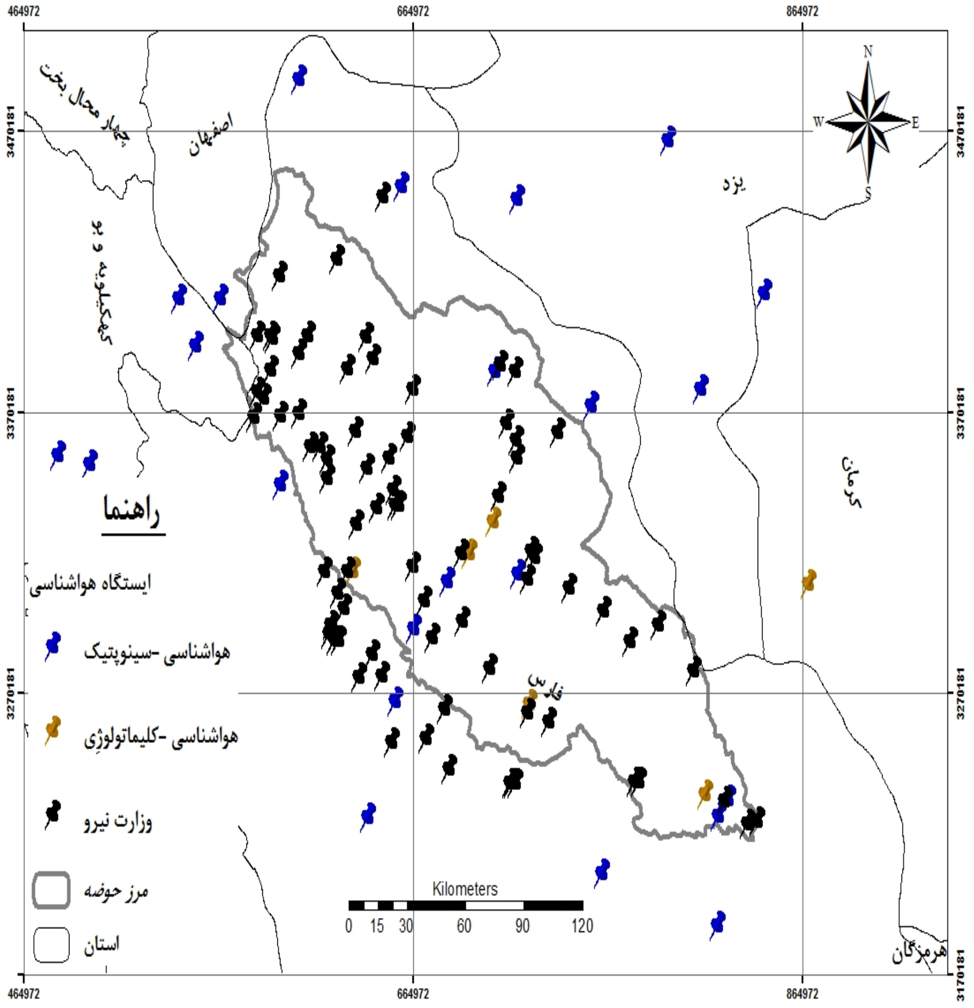
- Aster 30 meter DEM
- Three Land use maps for 1981, 2007 and 2015 (LANDSAT Images)
- Soil Map with 13 soil class
- Stream network layers, Location tables of dams and meteorological and hydrometric stations
- Local Information

✓ **56 sub basin**

✓ **2245 HRUs in order to apply agricultural management practices in area includes:**

✓ **18 Irrigated crops and 7 rain-fed crops**

Meteorological information



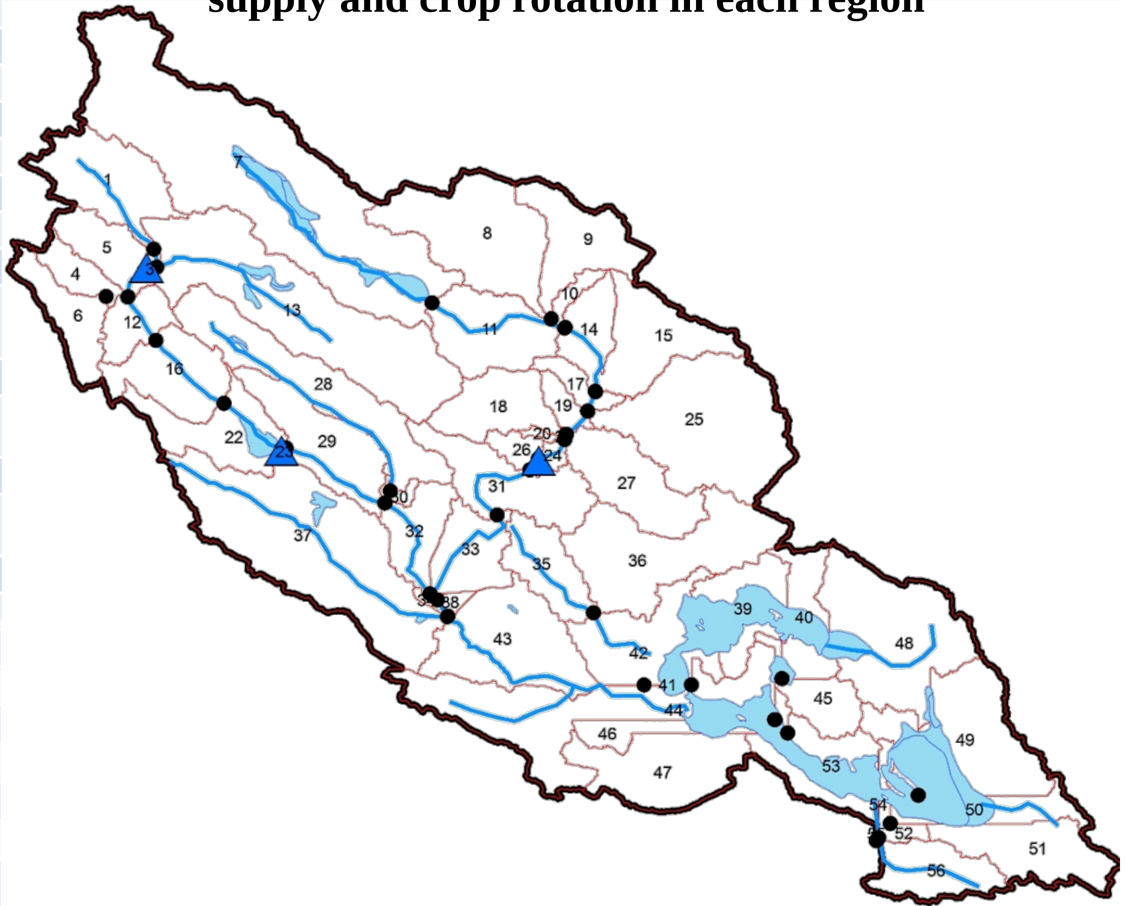
Meteorological information includes 3 synoptic stations and 12 rain gauge stations and 9 climatological stations

Station Type	During the period	Height	latitude	Longitude	Station name
synoptic	2000-2009	1620	30° 13´	52° 26´	Sad Doroodzan
synoptic	1989-2008	1596	29° 47´	52° 43´	Zarghan
synoptic	1989-2008	1596	29° 47´	52° 43´	Shiraz
climatological	1957-1989	2303	30° 16´	51° 59´	Ardakan- Fars
climatological	1971-2013	1880	29° 16´	52° 14´	Cheshme Bonab
climatological	1970-1987	1605	29° 56´	52° 54´	Takht Jamshid
climatological	1968-1980	1630	29° 31´	54° 19´	Kharameh
climatological	1974-2007	1690	29° 9´	54° 4´	Estahban
climatological	1964-2003	1632	29° 11´	52° 19´	Neiriz
climatological	1996-2010	1690	29° 55´	52° 19´	Arsanjan
climatological	1996-2003	1650	29° 57´	53° 23´	Tele Beiza
climatological	1995-2013	1600	29° 48´	53° 44´	Abadeh Tashk
rain gauge	1966-2015	2207	30° 23´	52° 41´	Ahmadabad Chahardangeh
rain gauge	1968-2015	1966	30° 37´	51° 58´	Jamalbeig
rain gauge	1967-2014	1580	29° 30´	53° 20´	Jahan abad bakhteghan
rain gauge	1966-2014	1779	30° 28´	52° 6´	Chamriz
rain gauge	1972-2015	2001	30° 33´	51° 54´	Chubkhaleh
rain gauge	1968-2015	1966	30° 37´	51° 58´	Jamalbeig
rain gauge	1970-2009	2101	30° 40´	52° 07´	Dehkadeh sefid
rain gauge	1986-2014	2197	30° 44´	52° 10´	Sadeh
rain gauge	1987-2015	1566	29° 16´	53° 54´	Sahl abad
rain gauge	1977-2014	2184	30° 32´	52° 21´	Kaftar
rain gauge	1985-2015	1849	30° 12´	53° 11´	Madar soleyman
rain gauge	1969-2014	1639	29° 59´	52° 42´	Mehrabad ramjerd

Cropping Pattern and Management Information

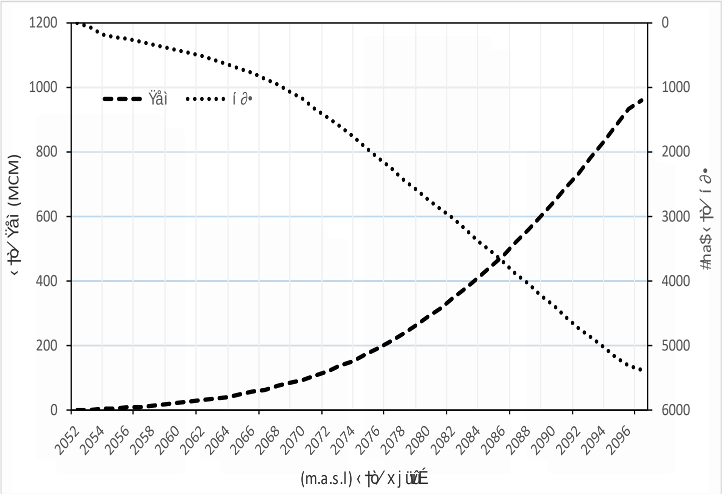
Type	Crop	Crop Area (%)	Fertilizer (Kg/Ha)			Irrigation (mm)	Yield (Kg/ha)
			Nitrate	Phosphate	Manure		
Irrigated	Apple	1/2	200	150	25000	880	25000-3400
Irrigated	Plum	0/1	200	150	25000	744	25000-4500
Irrigated	Almond	2/4	200	200	_	1022	3500-200
Irrigated	Fig	0/0	200	200	-	300	4000-800
Irrigated	Olive	4/5	250	200	20000	1266	16000-600
Irrigated	Saffron	1/0	-	-	-	300	4
Irrigated	Wheat	2/49	200	100	25000	476	5800-1000
Irrigated	Barley	4/4	200	100	25000	410	4500-400
Irrigated	Sunflower	3/6	70	45	28000	577	8800-1000
Irrigated	Rapeseed	8/1	100	100	_	916	4200-1400
Irrigated	Sugar Beet	4/3	170	260	1900	1168	44100-3200
Irrigated	Tomato	6/2	80	100	10000	772	70000-6000
Irrigated	Potato	9/0	150	100	_	853	36000-16000
Irrigated	Onion	5/0	100	80	30000	861	89000-7000
Irrigated	Alfalaf	3/3	100	100	21000	1123	66000-4000
Irrigated	Beans	2/8	100	150	10000	729	3500-1000
Irrigated	Rice	3/6	2.5	2.5	_	772	5000-3000
Rain Fed	Lentils	2/0	65	18	_	_	762
Rain Fed	Pea	2/6	_	18	_	_	347
Rain Fed	Barley	9/5	200	100	25000	_	400-4500
Rain Fed	Wheat	2/13	200	100	25000	_	1000-5800
Rain Fed	Almond	4/20	200	200	_	_	200-3500
Rain Fed	Fig	9/34	200	200	-	_	800-4000
Rain Fed	Grape	3/19			25000		4200-1000

- ✓ **Catchment management information including: cropping patterns, date of planting and harvesting, Irrigation and Fertilization planning, Source of water supply and crop rotation in each region**



Dams and Lakes data

- ✓ **Physical information and operation of dams, including Doroodzan, Sivand and Mulla Sadra and also the Lakes**



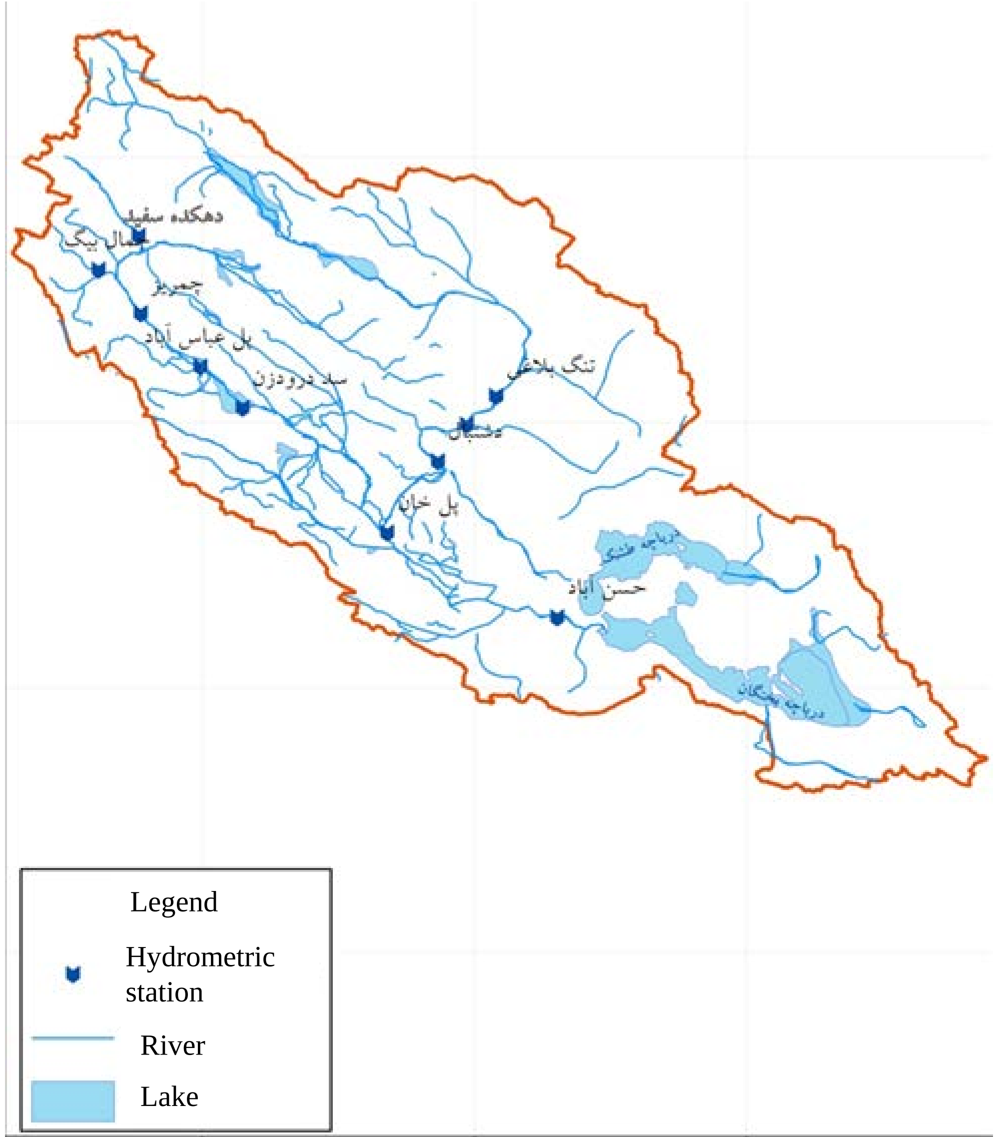
Volume MCM		operation Year	geographical location		Dam
useful	normal		latitude	Longitude	
860	993	1351	30° 12’ 20”	52° 25’ 06”	Doroodzan
411	440	1386	30° 38’ 30”	52° 04’ 55”	Mulla Sadra
142	150	1388	30° 08’ 32”	53° 05’ 01”	Sivand

✓ Domestic and the industrial water uses

industry (MCM)	Drinking (MCM)	Areas
0.13	1.94	**Tavabe arsanjan**
0.71	1.98	**arsanjan**
0.66	8.43	**Seydan farugh**
1.01	4.27	**Abadeh tashk**
0.01	0.39	**Khaneh kat**
0	1.21	**Khir**
0.1	4.47	**Estahban**
1.35	5.54	**Neyriz**
0.78	0.7	**Tange hana**
1.95	29.98	**Marvdasht- kharameh**
0.21	2.61	**Daryan**
1.47	1.72	**Saadatabad**
0	0.57	**Sarpaniran**
1.45	2.63	**Ghaderabad**
0.66	6.32	**Dehbid**
2	5.2	**Namdan**
10.08	9.1	**Beyza- zarghan**
1.64	11.17	**Dezkord- kamfirooz**
4.39	11.16	**Khosrow Shirin**
0.01	2.01	**Aspas**
0	1.72	**Bakan**

✓ Characteristics of aquifers

Calibration Data



- ✓ Hydrometric Data (11 Stations and 37 years)
- ✓ Ground Water Level (22 Aquifer)
- ✓ Crop Yield (26 Crops)
- ✓ Evapotranspiration (26 crops)

During the period	Height	Latitude	Longitude	Station Name
1974-2014	2100	30° 40´	52 ° 7 ´	Dehkadeh sefid
1970-2014	1900	30° 35´	51 ° 58 ´	Jamalbeyg- shirin
1964-2014	1840	30° 28´	52 ° 06 ´	Chamriz
2010-2014	1686	30° 19´	52 ° 16 ´	Abbasabad
1985-2014	1900	30° 10´	53 ° 09 ´	Tange balaghi
1967-2014	1646	30° 13´	52 ° 26 ´	Sad doroodzan
1991-2014	1761	30° 6´	53 ° 04 ´	Rahmat abad
1959-2014	1660	30° 1´	52 ° 58 ´	Dashtbal
1964-2014	1606	29° 20´	52 ° 47 ´	Pol khan
1997-2014	1573	29° 35´	53 ° 20 ´	Hasan abad kharameh

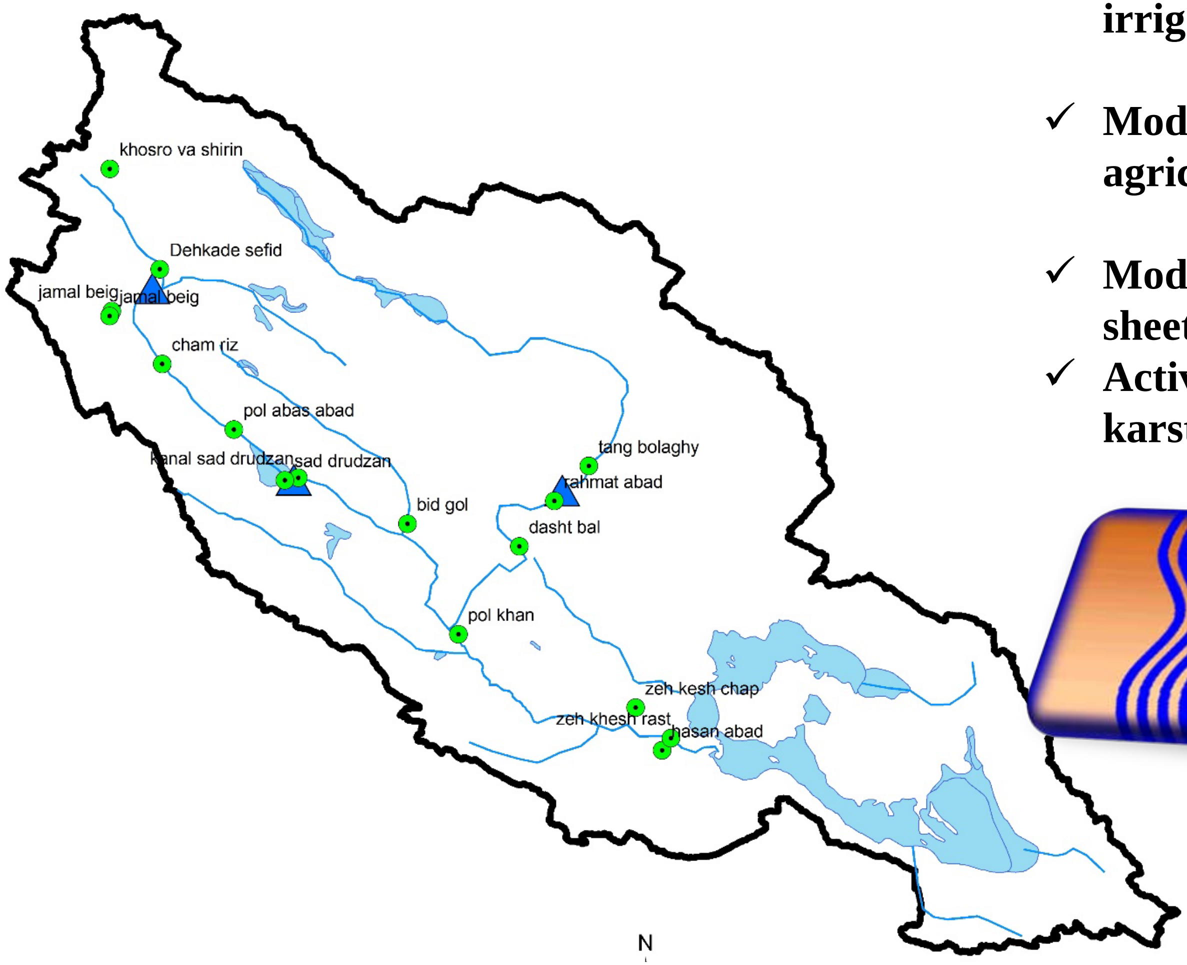
Development of SWAT-FARS package

- Modified SWAT model to simulate specific conditions of the study area
- Sub program for applying Dynamic changes of land use
- Sub program of extraction and analysis of model outputs based on the WA+ water accounting framework

Takhte Jamshid Ancient inscriptions

Modification of SWAT model

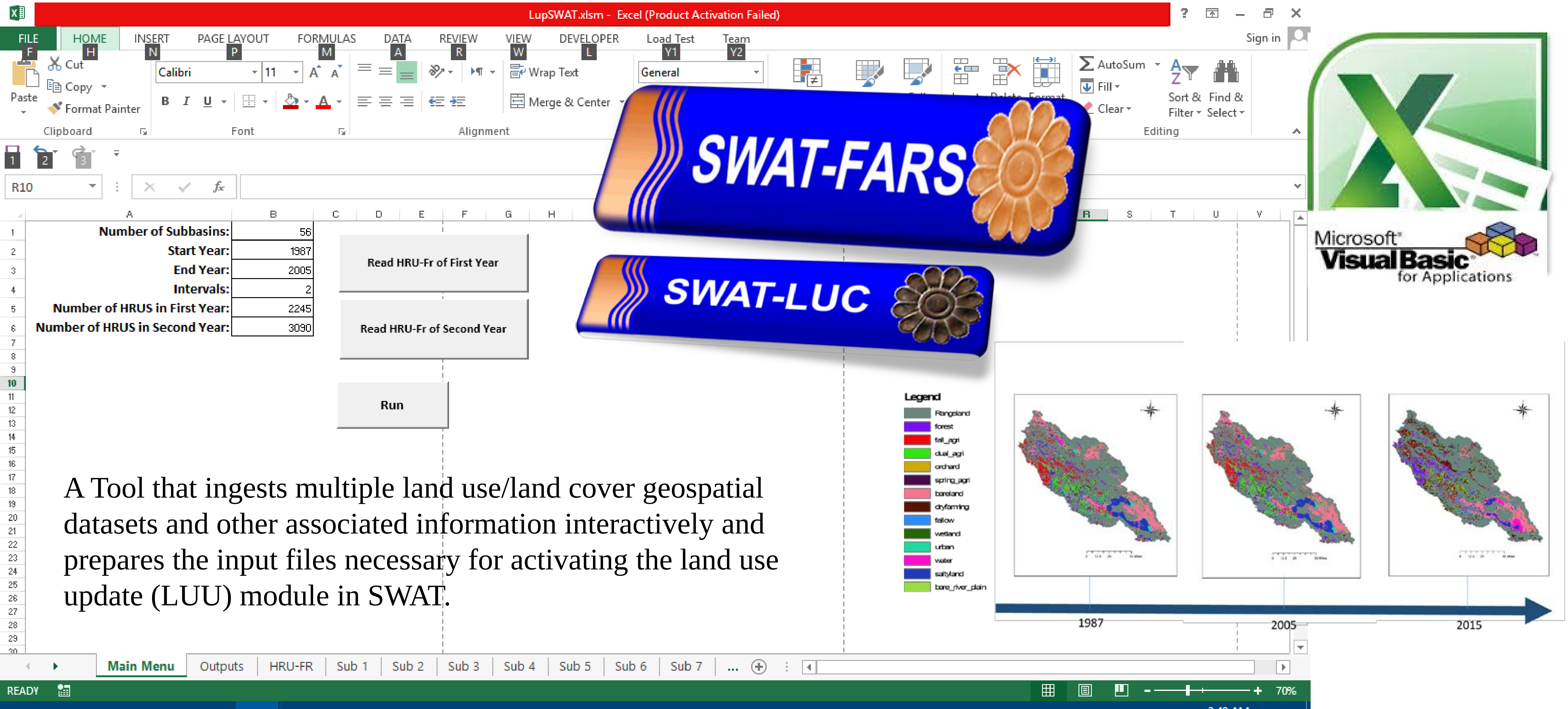
The SWAT-FARS is designed to simulate the complex agro-ecosystems and quantify the irrigation impacts on water cycle and actual water losses in a large scale karsty basin



- ✓ **Modify the model to simulate the interaction of aquifers and report the groundwater level**
- ✓ **Modify the SWAT model irrigation modules for simulation of irrigation systems and field water losses**
- ✓ **Modify the model to simulate the effects of salinity changes on agricultural production**
- ✓ **Modify the model for linking its outputs to the WA+ water accounting sheets**
- ✓ **Activation and application of crack flow modules to simulate flow in karst areas**

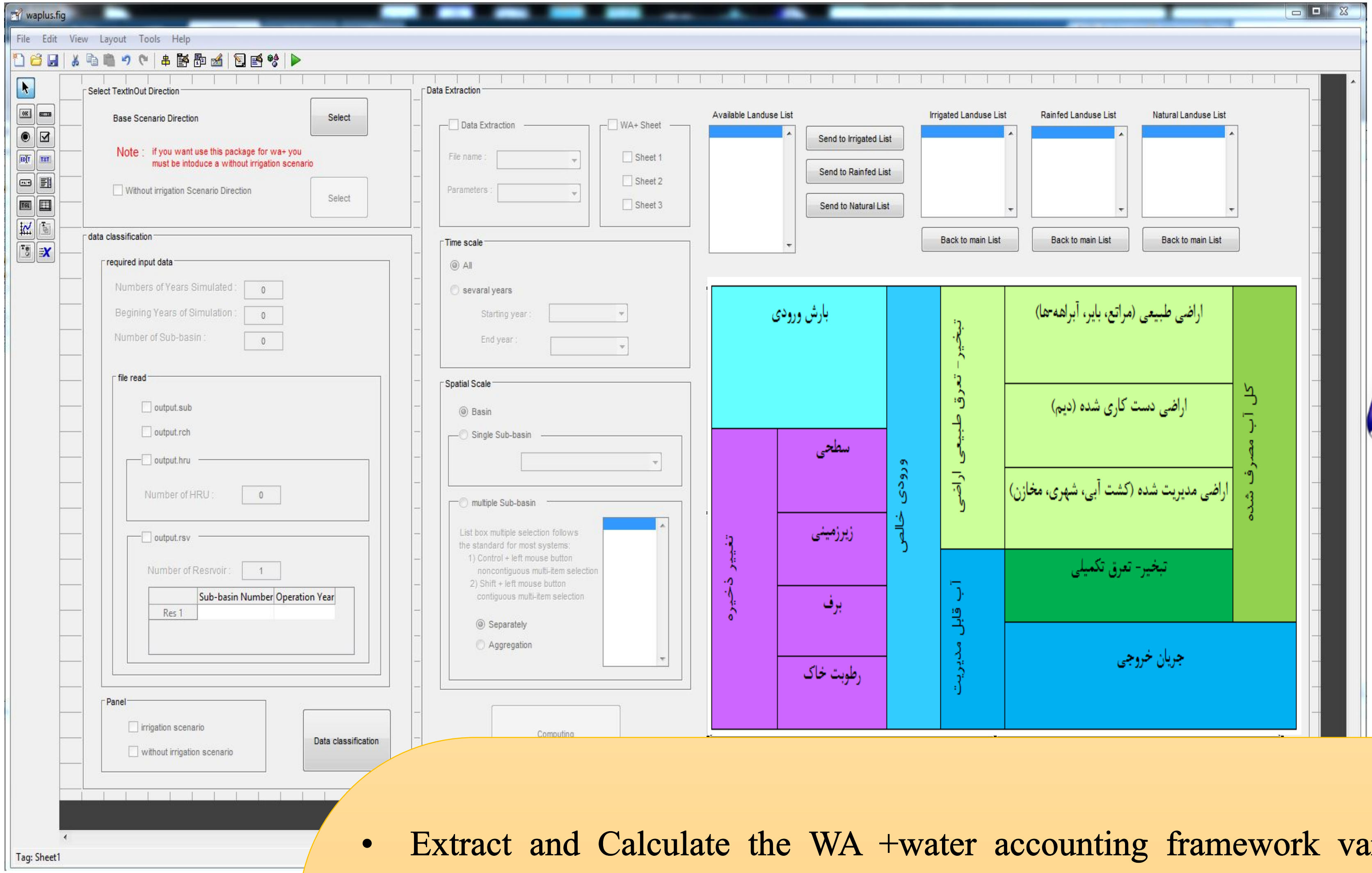
SWAT-FARS

SWAT-LUC for activating the dynamic land use changes in SWAT model



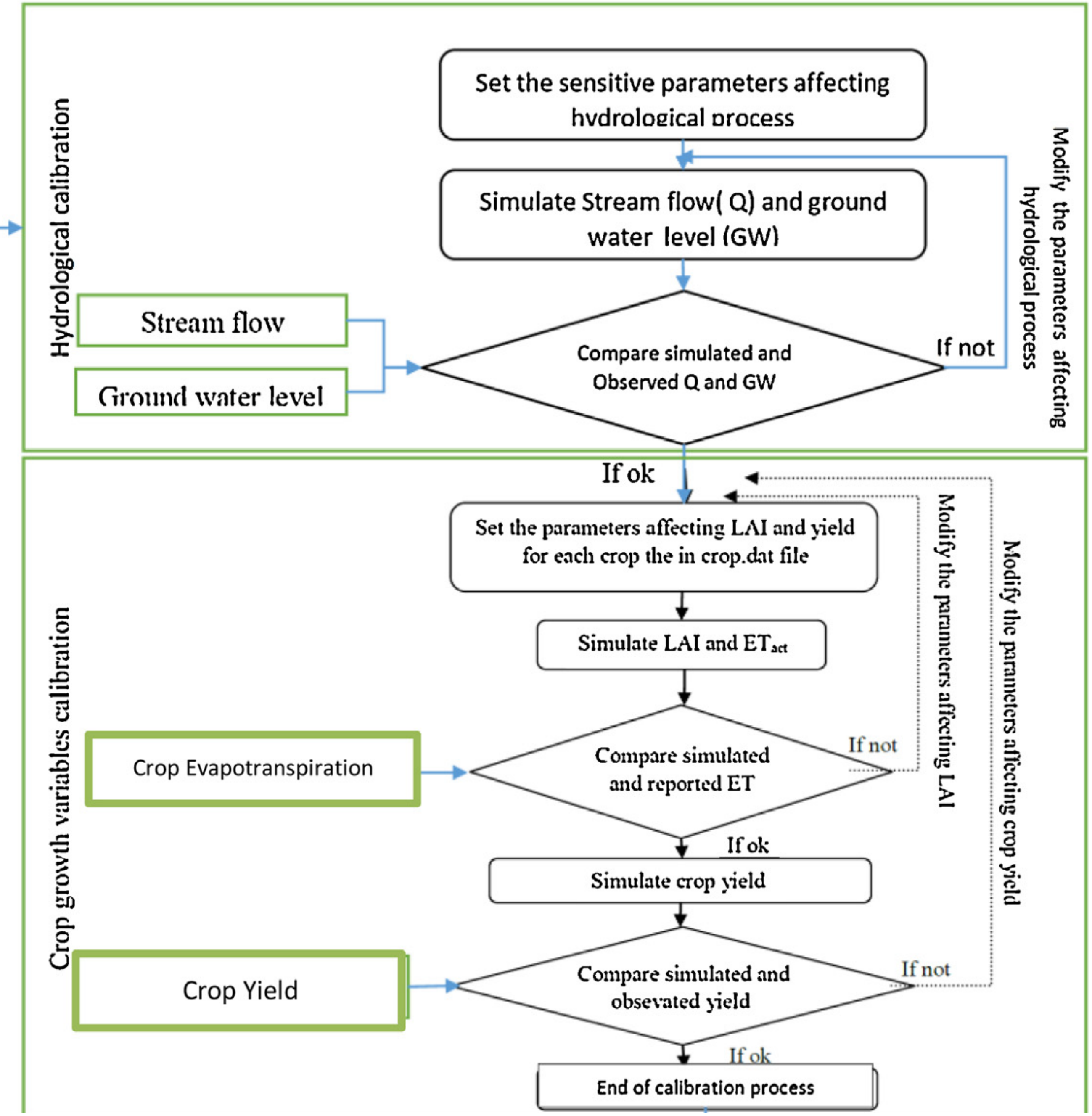
A Tool that ingests multiple land use/land cover geospatial datasets and other associated information interactively and prepares the input files necessary for activating the land use update (LUU) module in SWAT.

SWAT- WA^{+}



- Extract and Calculate the WA +water accounting framework variables from output files of the SWAT-FARS model

- Processing outputs of SWAT-FARS model



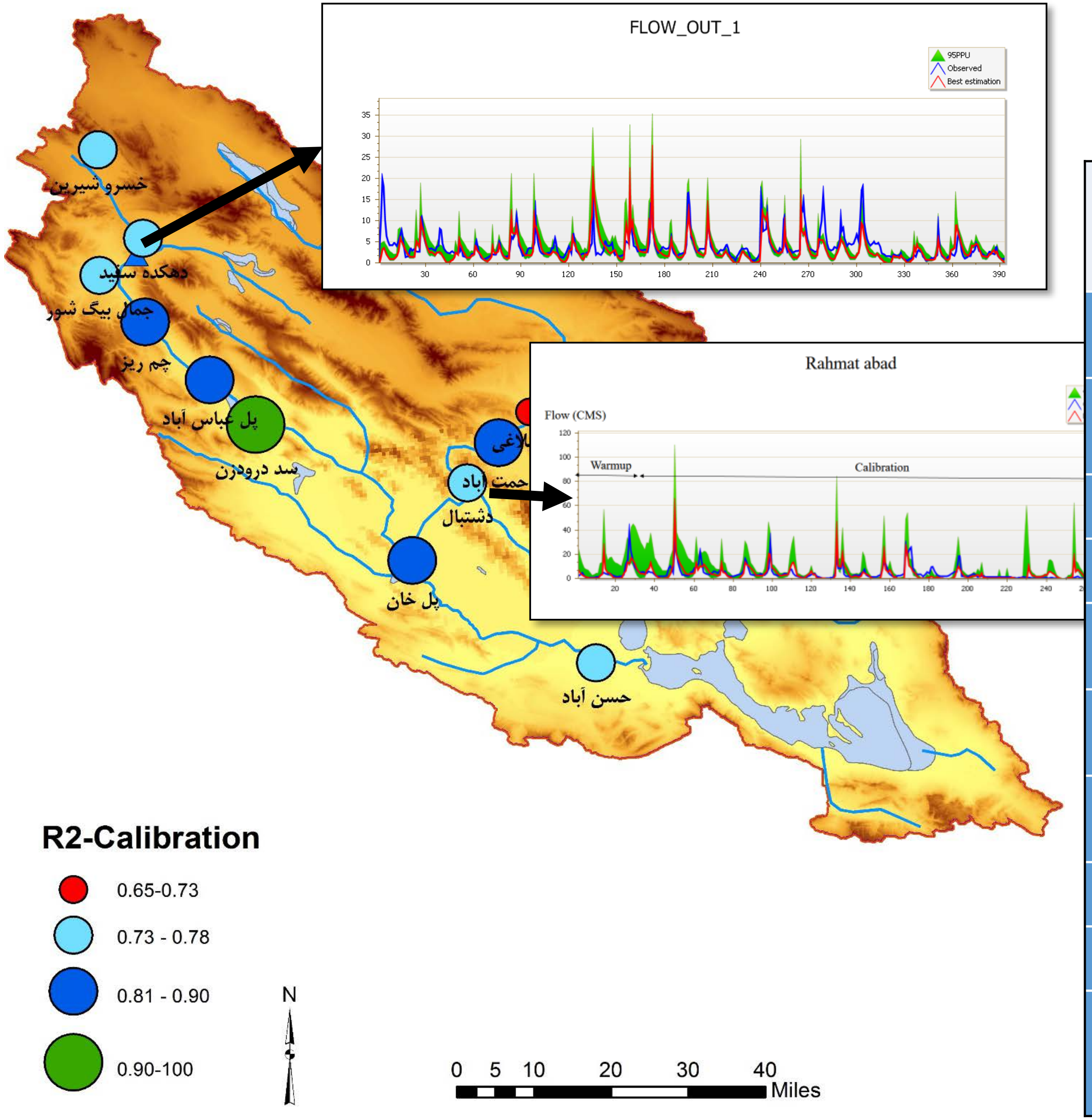
Model Calibration and validation

- Analysis extreme conditions
- Calibration of flow (observation data)
- Calibration and control of base flow (observation data)
- Calibration of groundwater level changes and control the withdrawal (the observed and estimated data)
- Calibration of crop yield (observations)
- Calibration of evapotranspiration (National Water Doc)

Using SUFI-2 algorithms and parallel processing version of the in SWAT-CUP to speed up the calibration of model

Simultaneous approach

Calibration and Validation flow



Station Name	calibration			Validation		
	R2	RMSE(m3/s)	NS	R2	RMSE(m3/s)	NS
Dehkadeh sefid	0.74	9.5	0.69	0.68	3.51	0.58
Jamalbeig-shirin	0.78	9.93	0.6	0.88	14.14	0.52
Chamriz	0.82	94.45	0.61	0.81	70.32	0.6
Abbasabad	*	*	*	0.85	7.34	0.96
Tange balaghi	0.65	2.38	0.58	0.67	2.91	0.5
Sad doroodzan	0.99	5.94	0.98	0.98	9.46	0.96
Rahmat abad	0.81	9.28	0.59	0.5	1.32	0.55
Dashtbal	0.76	50.39	0.52	0.85	19.34	0.5
Pole khan	0.9	118.94	0.76	0.89	19.58	0.79
Hasan abad kharameh	0.73	1.04	0.58	0.7	0.9	0.51

Calibration of Base flow

R2	RMSE(cms)	NS	
0.58	0.66	0.73	Dehkadeh sefid (Upstream of mulla sadra dam)
0.75	0.22	0.74	Jamalbeig
0.67	1.77	0.56	Tange balaghi (Upstream of Sivand dam)
0.95	3.16	0.90	Abbas abad (Upstream of Doroodzan dam)

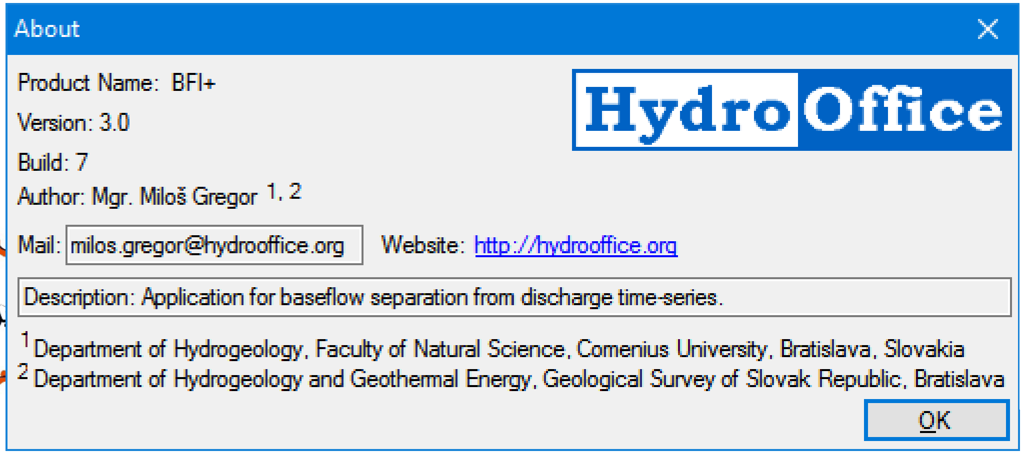
Recursive digital filter

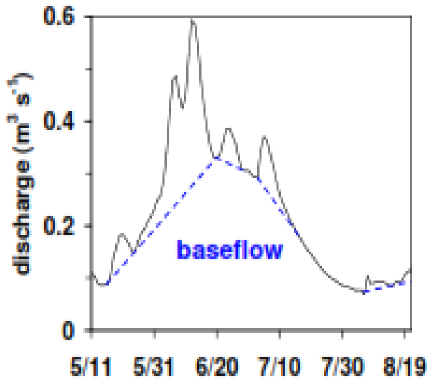
The algorithm, originally described by Nathan & McMahon (1990), calculates the quick flow component q_i at time step i from q_{i-1} at previous time step and total flow Q_i and Q_{i-1}:

$$q_i = \beta q_{i-1} + \frac{1+\beta}{2}(Q_i - Q_{i-1})$$

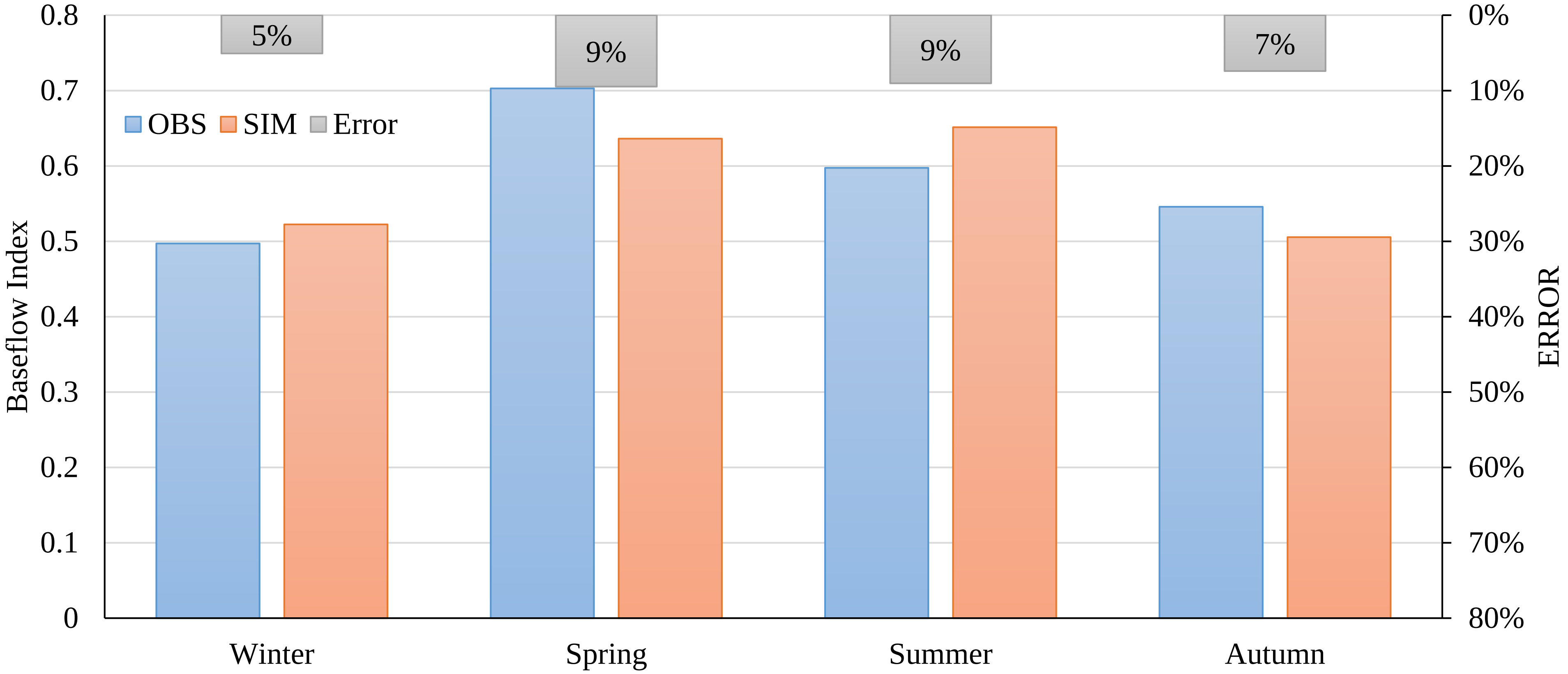
where β is a filter constant ranging between 0.9 and 0.95.

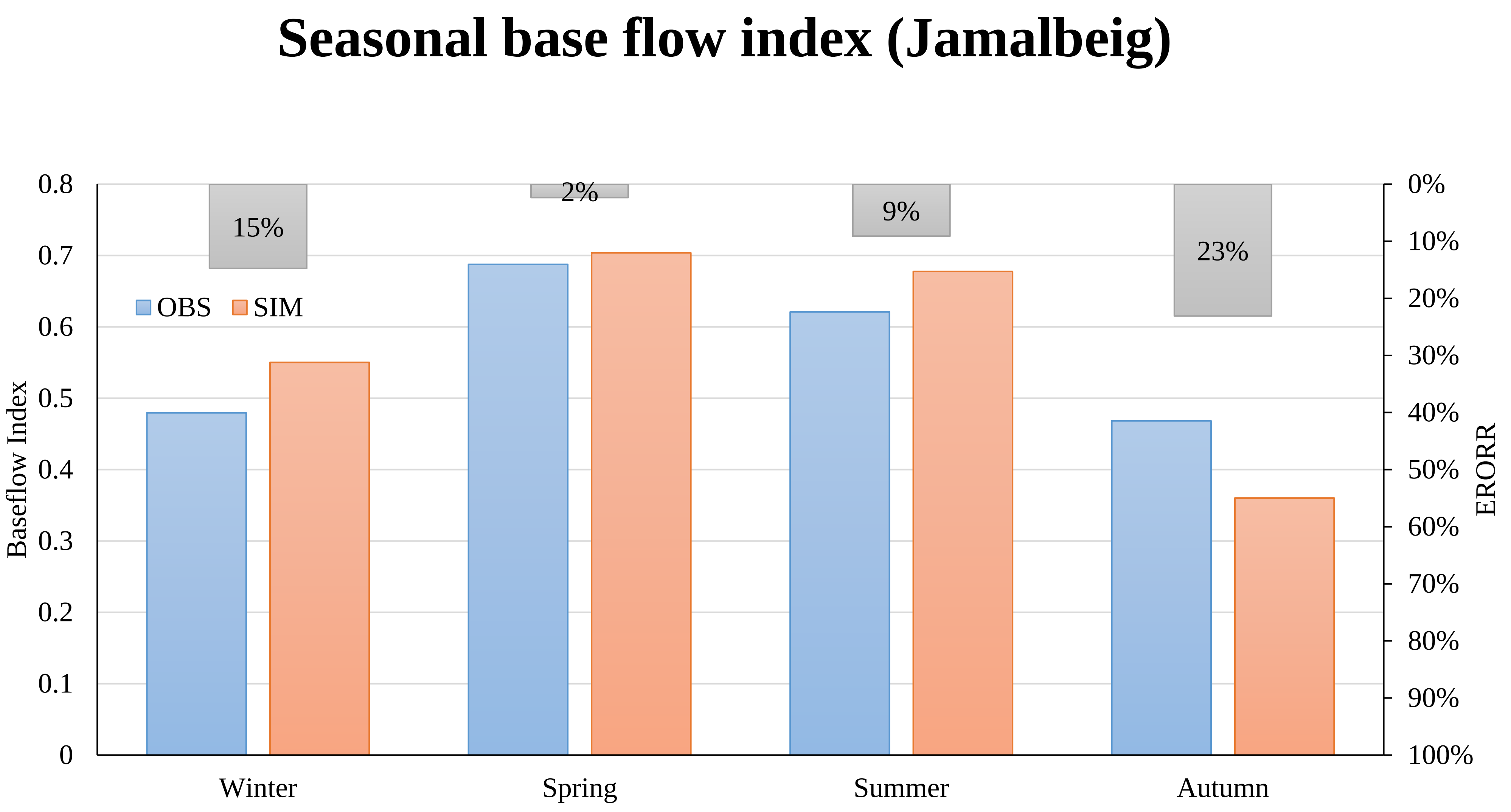
Baseflow b_i is calculated as: $b_i = Q_i - q_i$





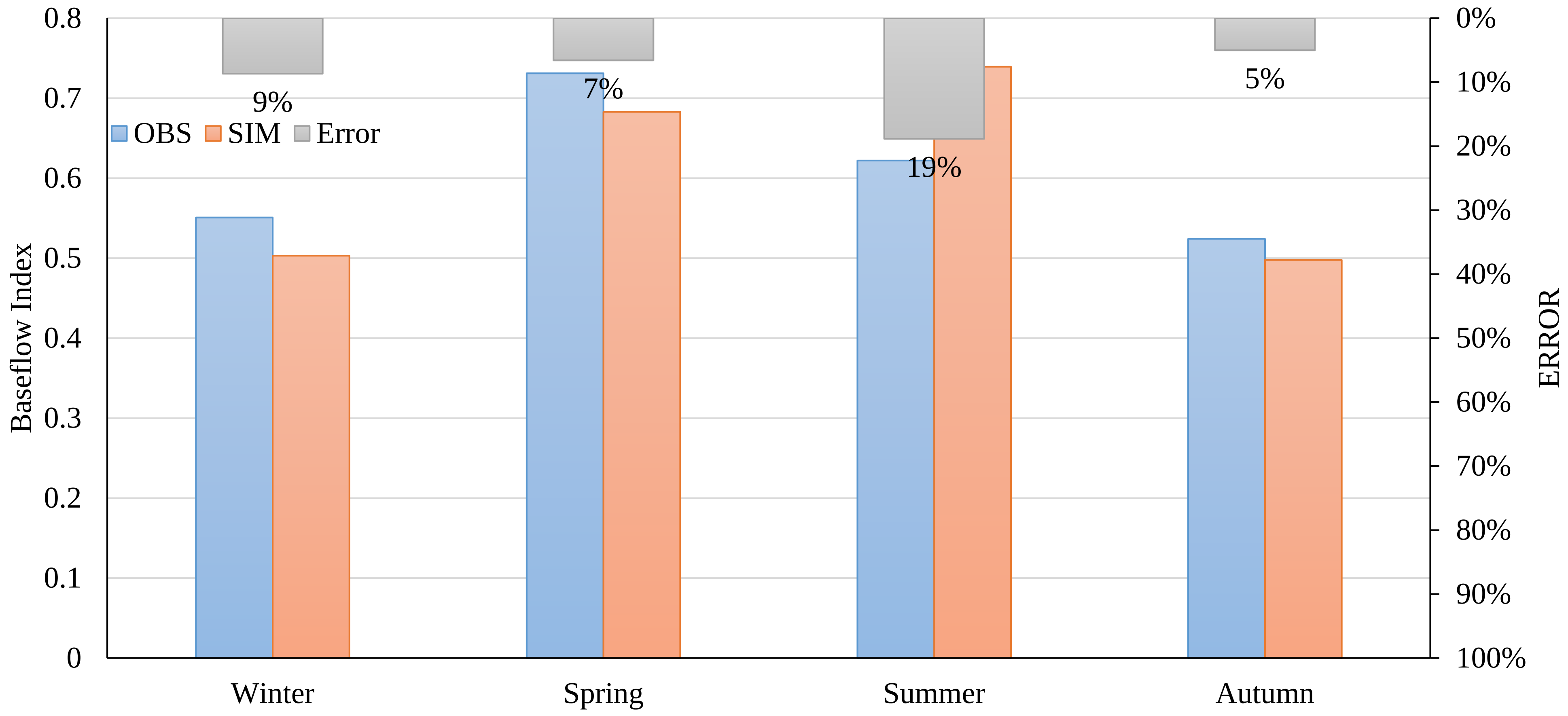
Seasonal base flow index (upstream of Mulla Sadra Dam)



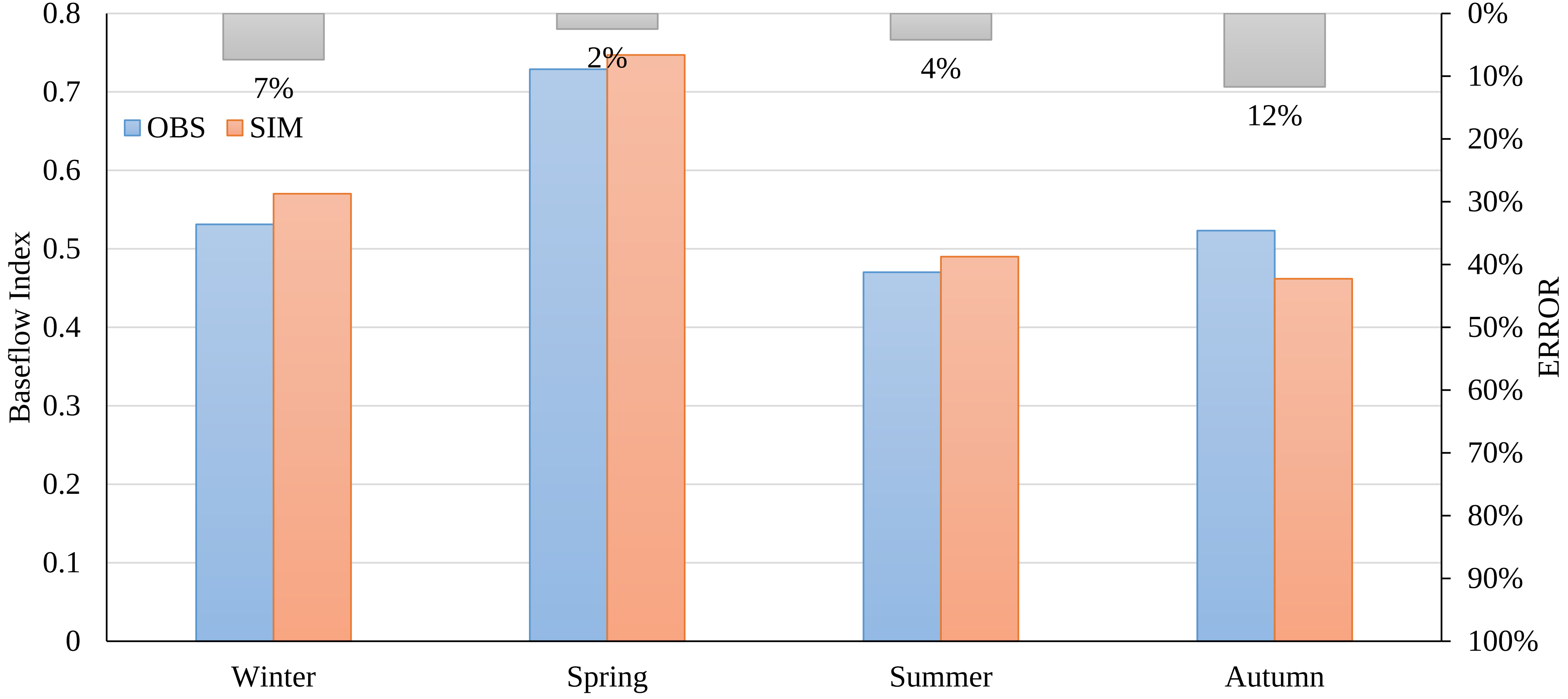


Seasonal base flow index (Jamalbeig)
Baseflow Index
ERORR
OBS
SIM
15%
2%
9%
23%
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0%
10%
20%
30%
40%
50%
60%
70%
80%
90%
100%
Winter
Spring
Summer
Autumn

Seasonal base flow index (upstream of Sivand Dam)



Seasonal base flow index (upstream of Doroodzan Dam)

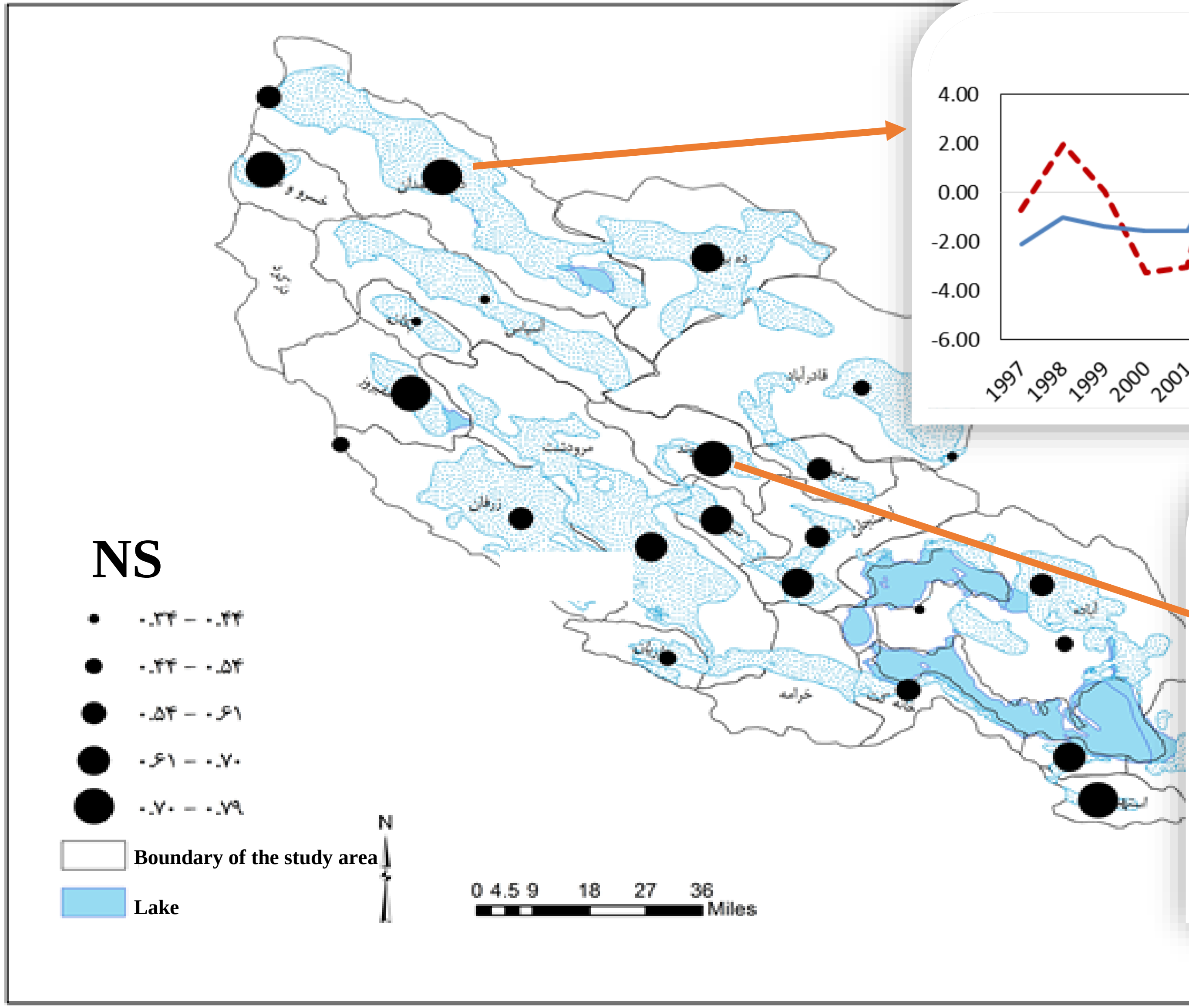


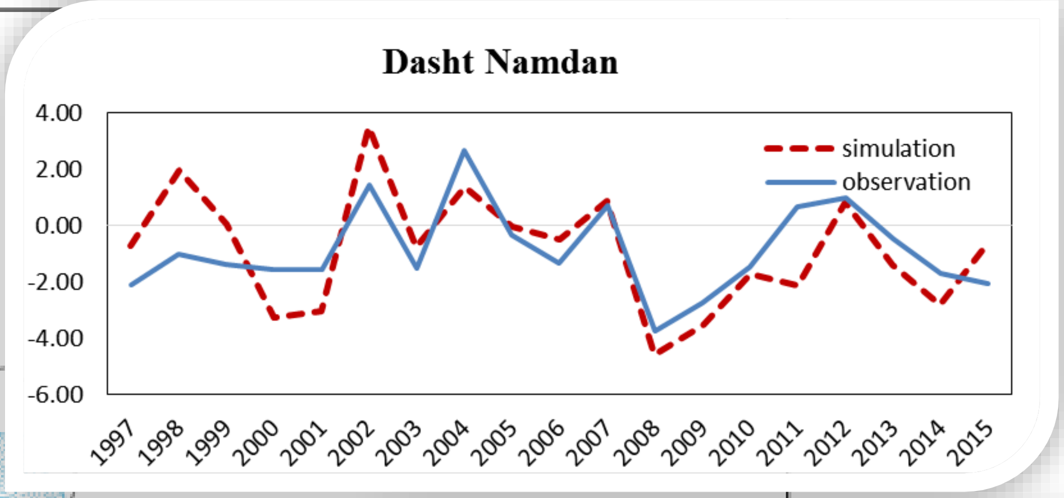
Performance of model on simulation of the Crop yields and evapotranspiration

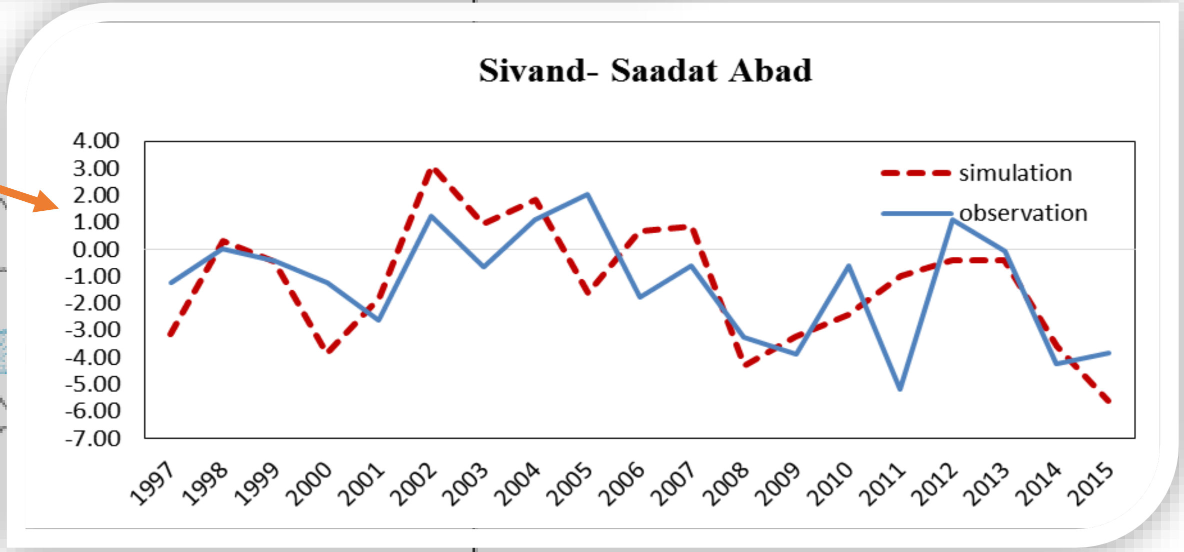
		Apple	Peach	Almond	Olive	Wheat	Barley	Canola	Sugar beet	tomato	potato
Evapotranspiration	**R2**	0.98	0.83	-	0.79	0.5	0.41	0.95	0.92	0.89	0.94
	Ns	0.98	0.81	-	0.47	0.67	0.58	0.94	0.92	0.85	0.94
Yeild	**R2**	0.92	0.83	0.62	0.83	0.66	0.76	0.90	0.60	0.48	0.62
	Ns	0.92	0.80	0.52	0.35	0.27	0.68	0.89	0.61	0.51	0.47
		Alfalfa	Beans	Rice	Sunflower	onion	Lentil	Barley Rainfed	Wheat Rainfed	Figs	Almond Rainfed
Evapotranspiration	**R2**	0.93	0.88	0.92	0.84	0.93	-	-	-	-	-
	Ns	0.76	0.76	0.90	0.78	0.92	-	-	-	-	-
Yeild	**R2**	0.97	0.88	0.92	0.25	0.77	0.99	0.59	0.90	0.86	0.62
	Ns	0.93	0.86	0.91	0.63	0.53	0.47	0.48	0.63	0.84	0.52

Irrigated   Rainfed

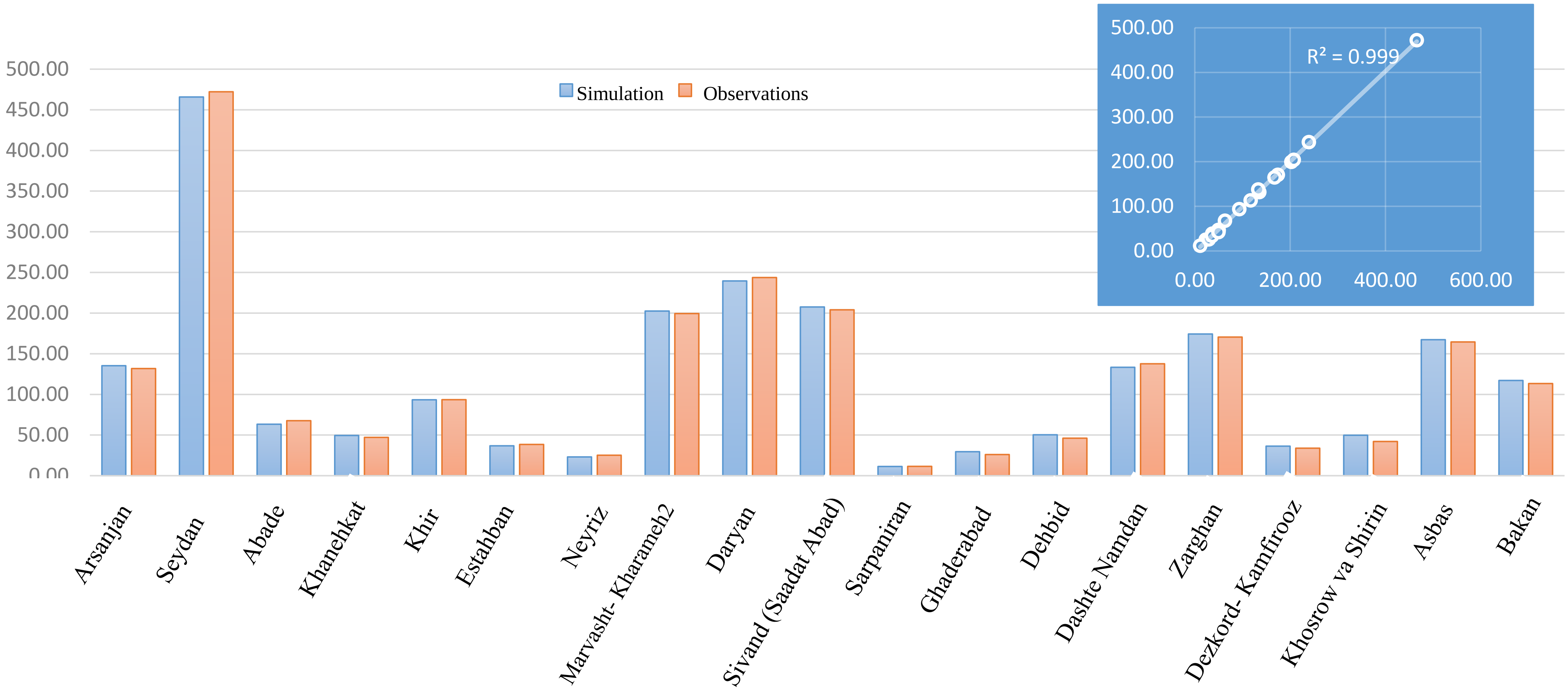
Calibration of groundwater level changes



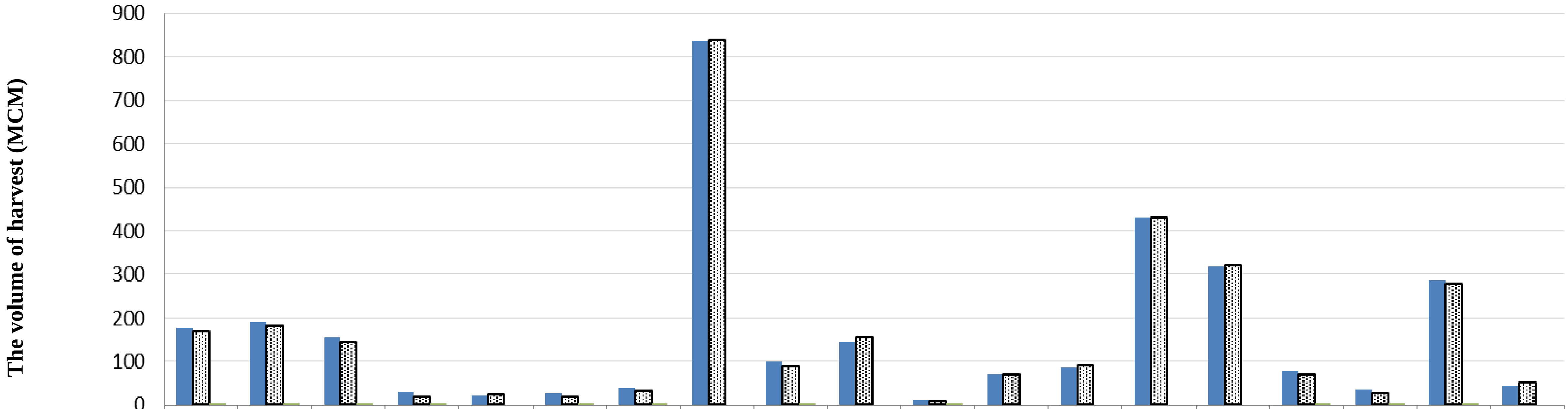




Compare the groundwater recharge (mm) with national documents



Compare the groundwater withdrawals and observed data



	Arsanjan	Seydan	Abade	Khaneh kat	Khir	Estahban	Neyriz	Marvasht-Kharameh	Daryan	Sivand (Saadat Abad)	Sarpaniran	Ghader abad	Dehbid	Dashte Namdan	Zarghan	Dezkord-Kamfirooz	Khosrow Shirin	Asbas	Bakan
simulation	177.89	189.69	154.55	31.22	22.68	28.31	38.04	837.33	98.34	144.97	10.3	69.21	84.97	429.86	317.92	77.8	34.35	286.63	44.4
data Inventory 1388	169.89	183.69	145.55	20.22	24.68	20.31	34.04	840.33	88.34	154.97	7.91	71.21	91.97	430.86	321.92	70.8	26.35	278.63	52.4
Difference Percent	5%	3%	6%	54%	-8%	39%	12%	0%	11%	-6%	30%	-3%	-8%	0%	-1%	10%	30%	3%	-15%

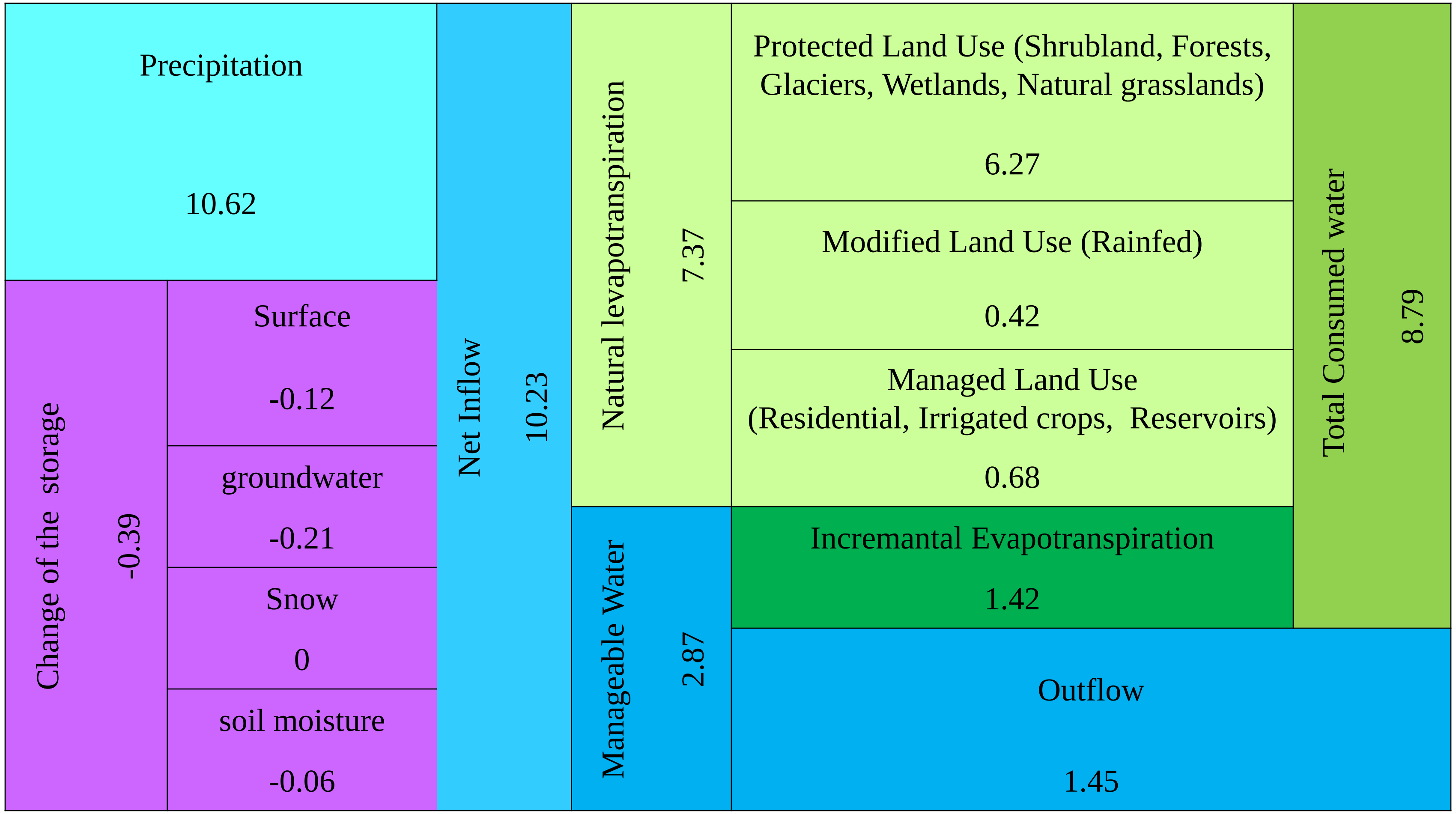
Capabilities of SWAT-FARS Model

- ✓Simulation and spatial and temporal analysis of water balance components in the different climatic and management conditions
- ✓Calculating the potential of renewable water resources
- ✓Estimation of the green and blue water footprints
- ✓Analyzing the agricultural and water resources systems using WA+ water accounting framework
- ✓Assessing the impact of climate variability and human activities on water balance components
- ✓Simulation wide range of management strategies (e.g. structural development, type and cropping pattern, change the planting time, change the efficiency, etc.)
- ✓Separating withdrawal, consumption (depletion) and determine the real water saving based on the proposed management strategies

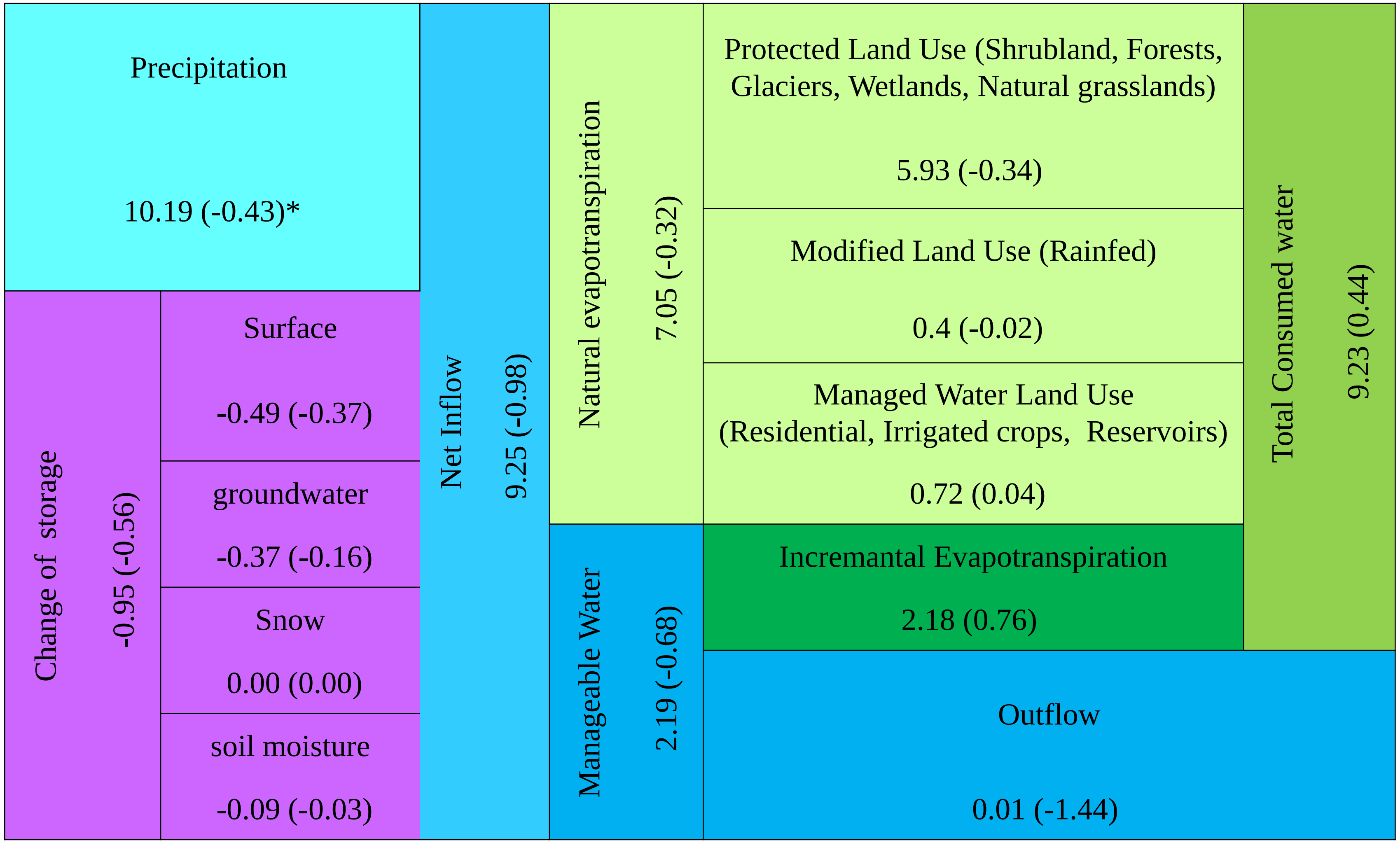
Report of Water Sources and Consumptions (mcm)

Results

1980-2006



2007-2014



Precipitation
10.19 (-0.43)*
Change of storage
-0.95 (-0.56)
Surface
-0.49 (-0.37)
groundwater
-0.37 (-0.16)
Snow
0.00 (0.00)
soil moisture
-0.09 (-0.03)
Net Inflow
9.25 (-0.98)
Natural evapotranspiration
7.05 (-0.32)
Protected Land Use (Shrubland, Forests, Glaciers, Wetlands, Natural grasslands)
5.93 (-0.34)
Modified Land Use (Rainfed)
0.4 (-0.02)
Managed Water Land Use (Residential, Irrigated crops, Reservoirs)
0.72 (0.04)
Manageable Water
2.19 (-0.68)
Incremantal Evapotranspiration
2.18 (0.76)
Total Consumed water
9.23 (0.44)
Outflow
0.01 (-1.44)

Extracted Indicators from the report of water resource and consumptions for different time periods

Amount	The analysis period	Calculation method	Description	Index
0.28	1985-2006	$\frac{Manageable\ Water}{Net\ input\ Water}$	What proportion of net input basin is programmable for consumption and downstream commitments ?	**The ratio of manageable water**
0.23	2007-2014			
-0.073	1985-2006	$\frac{Change\ the\ groundwater\ volume}{Manageable\ Water}$	What proportion of manageable water basin is originated the change volume of groundwater?	**The ratio of ground water resources change**
-0.16	2007-2014			
0.88	1985-2006	$\frac{Manageable\ Water - The\ downstream\ commitme}{Manageable\ Water}$	What proportion of water allocable basin is used for consumptions within basin ?	**The ratio of utilizable water**
0.85	2007-2014			
0.49	1985-2006	$\frac{Supplementary\ Evapotranspiration}{Manageable\ Water - The\ downstream\ commitme}$	What proportion of water allocable basin is consumed on it?	**Consumption ratio**
0.99	2007-2014			
4.47	1985-2006	$\frac{flowout}{The\ downstream\ commitments}$	What proportion of water commitments the downstream basin is supplied?	**The ratio of docommitments wnstream supply**
0.03	2007-2014			

Evapotranspiration Report

1980-2014

<table>
<tr><td rowspan="4">Protected Land Use (Shrubland, Forests, Glaciers, Wetlands, Natural grasslands)

6.17</td><td rowspan="6">Total evapotranspiration (Total Consumed water)

8.99</td><td rowspan="4">Non-Beneficial Evaporation
5.35</td><td>Soil Evaporation

4.54</td></tr>
<tr><td>Groundwater Evaporation

0.004</td></tr>
<tr><td>River Evaporation

0.13</td></tr>
<tr><td>Reservoirs Evaporation

0.67</td></tr>
<tr><td>Modified Land Use (Rainfed)

0.43</td><td rowspan="2">Beneficial Transpiration
3.64</td><td>Transpiration of Crops

2.23</td></tr>
<tr><td>Managed Land Use (Residential, Irrigated crops, Reservoirs)

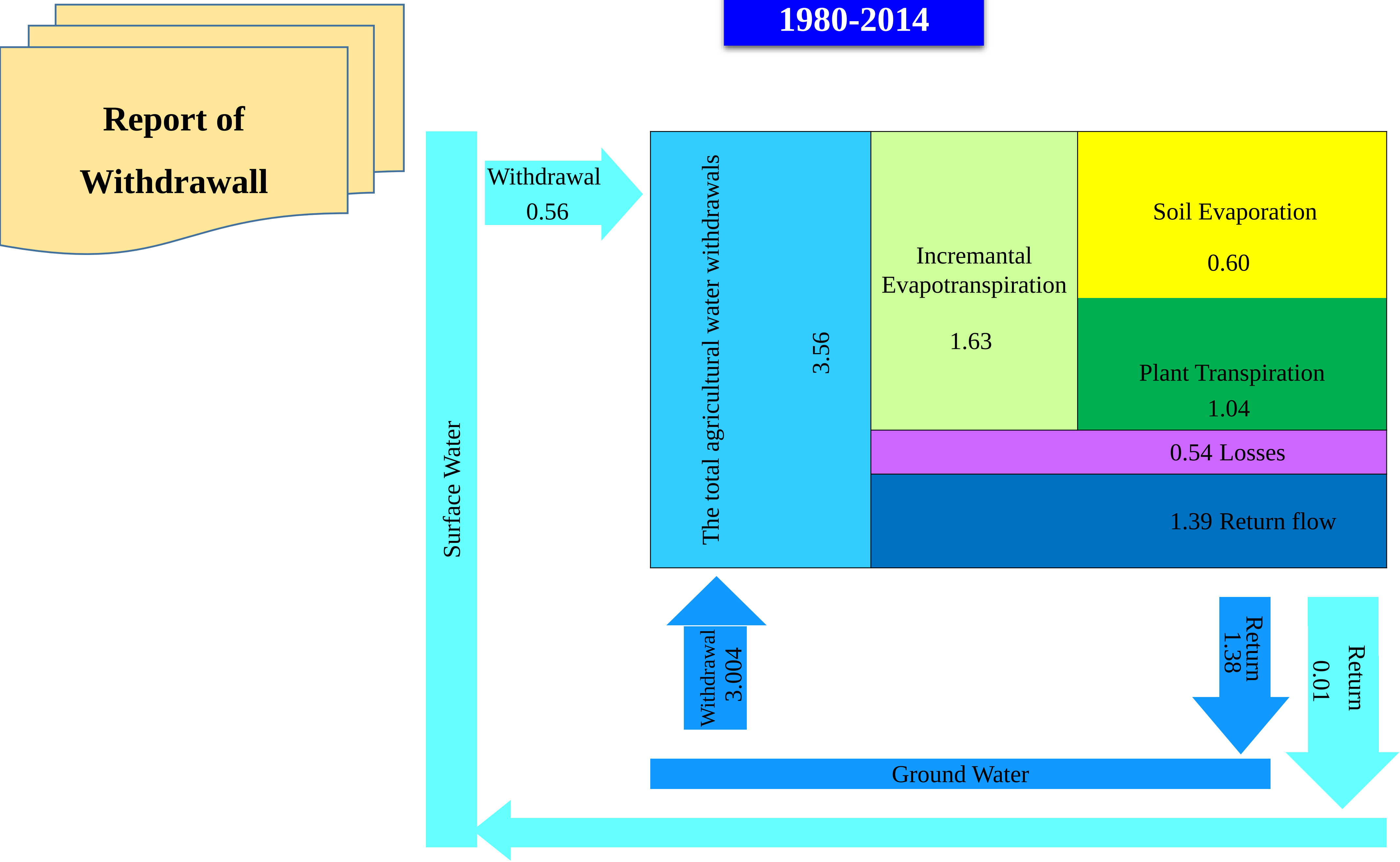
2.41</td><td>Transpiration of natural plants

1.42</td></tr>
</table>

Extracted Indicators from evapotranspiration report of the basin for different time periods

Amount	The analysis period	Calculation Method	Description	The Title of Index
0.41	*1985-2006*	$\frac{The\ Total\ Transpiration}{The\ Total\ Evapotranspiration}$	What part of the basin evapotranspiration has been spent for the plants Transpiration ? (How much the water consumptions of basin has been beneficial ?)	**Transpiration ratio (beneficial consumption of basin)**
0.43	*2006-2014*			
0.81	*1985-2006*	$\frac{Agriculture\ Transpiration}{Total\ agricultural\ evapotranspiration}$	What part of agricultural evapotranspiration has been spent for the plants Transpiration ? (How much of agricultural water use has been beneficial?)	**Agriculture Transpiration ratio (beneficial consumption of agriculture sector)**
0.81	*2006-2014*			
0.23	*1985-2006*	$\frac{Evapotranspiration\ of\ managed\ lands}{The\ Total\ Evapotranspiration}$	What part of basin water consumption have happened in the lands under management ?	**Manageable area consumption ratio**
0.31	*2006-2014*			
0.23	*1985-2006*	$\frac{Agricultural\ Evapotranspiration^{*}}{The\ Total\ Evapotranspiration}$	What part of basin water consumption has been spent agricultural production ?	**Agricultural Evapotranspiration ratio**
0.28	*2006-2014*			
0.83	*1985-2006*	$\frac{Irrigated\ agricultural\ evapotranspiration^{**}}{Agricultural\ Evapotranspiration}$	What part of the agricultural water use of basin has been supplied Through irrigation ?	**Irrigated Agricultural Evapotranspiration ratio**
0.87	*2006-2014*			

1980-2014


Report of
Withdrawall
Withdrawal
0.56
Surface Water
The total agricultural water withdrawals
3.56
Incremantal
Evapotranspiration
1.63
Soil Evaporation
0.60
Plant Transpiration
1.04
0.54 Losses
1.39 Return flow
Withdrawal
3.004
Return
1.38
Return
0.01
Ground Water

Extracted Indicators from Withdrawal report of basin for different time periods

Amount	The analysis period	Calculation Method	Description	The Title of Index
0.56	*1985-2006*	$\frac{groundwater\ Withdrawal}{The\ total\ agricultural\ water\ withdrawals}$	What part of the total water withdrawal for irrigation have been from basin groundwater ?	Groundwater Withdrawal ratio
0.88	*2006-2014*			
0.40	*1985-2006*	$\frac{Incremantal\ Evapotranspiration\ of\ irrigated\ lands}{The\ total\ agricultural\ water\ withdrawals}$	What part of the water withdrawal for irrigation has been spent crop evapotranspiration ?	Farm Efficiency
0.45	*2006-2014*			
0.73	*1985-2006*	$\frac{Incremantal\ Evapotranspiration\ of\ irrigated\ lands}{The\ total\ agricultural\ water\ withdrawals - \text{Return Water}}$	What part of the water used to irrigate has been spent the crop evapotranspiration?	Basin Efficiency
0.85	*2006-2014*			
0.43	*1985-2006*	$\frac{\text{Return Water}}{The\ total\ agricultural\ water\ withdrawals}$	What part of the water withdrawal for irrigation is back again to the water resources of basin?	The Return Water ratio
0.40	*2006-2014*			

Productivity Report

1980-2014

Water productivity

Crop	Cereals	Non-cereals				Fruit & vegetables			Oil-seeds	Feed crops	Beverage crops	Other crops	Agricultural water consumption		
		Root / tuber crops	Leguminous crops	Sugar crops	Merged	Vegetables & melons	Fruits & nuts	Merged							4.1
	0.67								-				ET	rainfed	0.7
	1.09					0.04	0.15						ET from rainfall	irrigated	1.3
	1.04		0.07			0.74	0.23						Incremental ET	irrigated	2.1
	2.14		0.09			0.78	0.39						Total ET	irrigated	3.4

Land productivity

Crop		Cereals	Non-cereals				Fruit & vegetables			Oil-seeds	Feed crops	Beverage crops	Other crops		
			Root / tuber crops	Leguminous crops	Sugar crops	Merged	Vegetables & melons	Fruits & nuts	Merged						
Land productivity		906	-	-	-	-	-	-	-	-	-	-	-	Yield	rainfed
		320	-	600	-	-	47	2,200	-	-	-	-	-	Yield from rainfall	irrigated
		1,286	-	139	-	-	8,636	5,649	-	-	-	-	-	Incremental yield	irrigated
		1,606	-	739	-	-	8,683	7,849	-	-	-	-	-	Total yield	irrigated
Water productivity		0.45	-	-	-	-	-	-	-	-	-	-	-	WP	rainfed
		0.32	-	0.67	-	-	0.44	1.43	-	-	-	-	-	WP from rainfall	irrigated
		0.65	-	1.23	-	-	8.19	2.37	-	-	-	-	-	Incremental WP	irrigated
		0.52	-	0.73	-	-	7.48	1.98	-	-	-	-	-	Total WP	irrigated

Discussion

- ✓The results showed that total average annual water depletion in the basin (9.23 km3) exceeded basin water inflows (9.24 km3) during the last decade. This suggest that the Task-Bakhtegan basin is nearly a closed basin in which more than 99 % of the available water is depleted.

- ✓The managed water use, chiefly dominated by irrigated agriculture, accounts for 28 % of depletion (ET) and about the 60% basin water depletions is vaporized non-beneficially into the atmosphere.

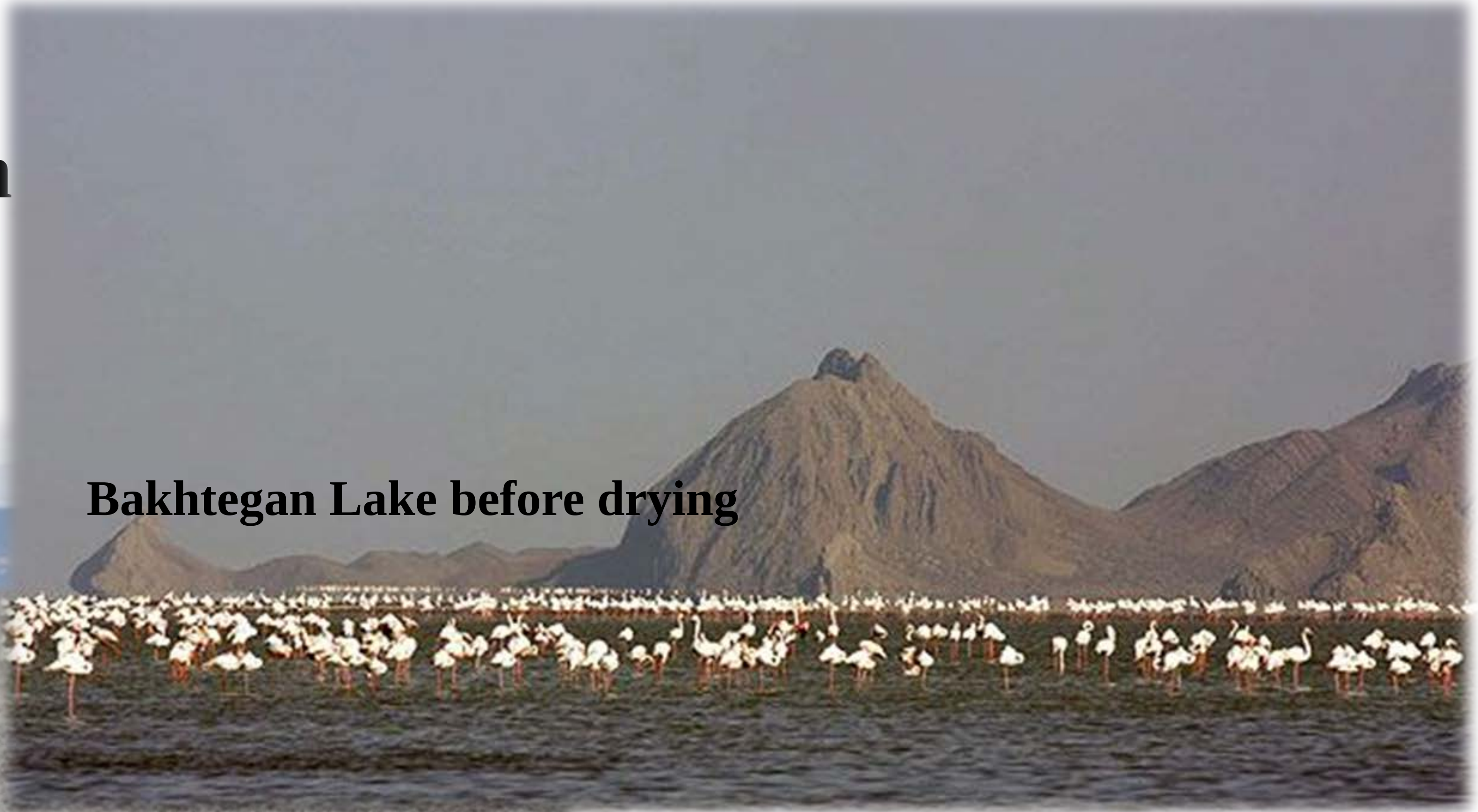
- ✓ Based on the results, loss of storage, low beneficial depletion, and low land and water productivity were identified as the main water resources management issues in the case study.

Conclusion:

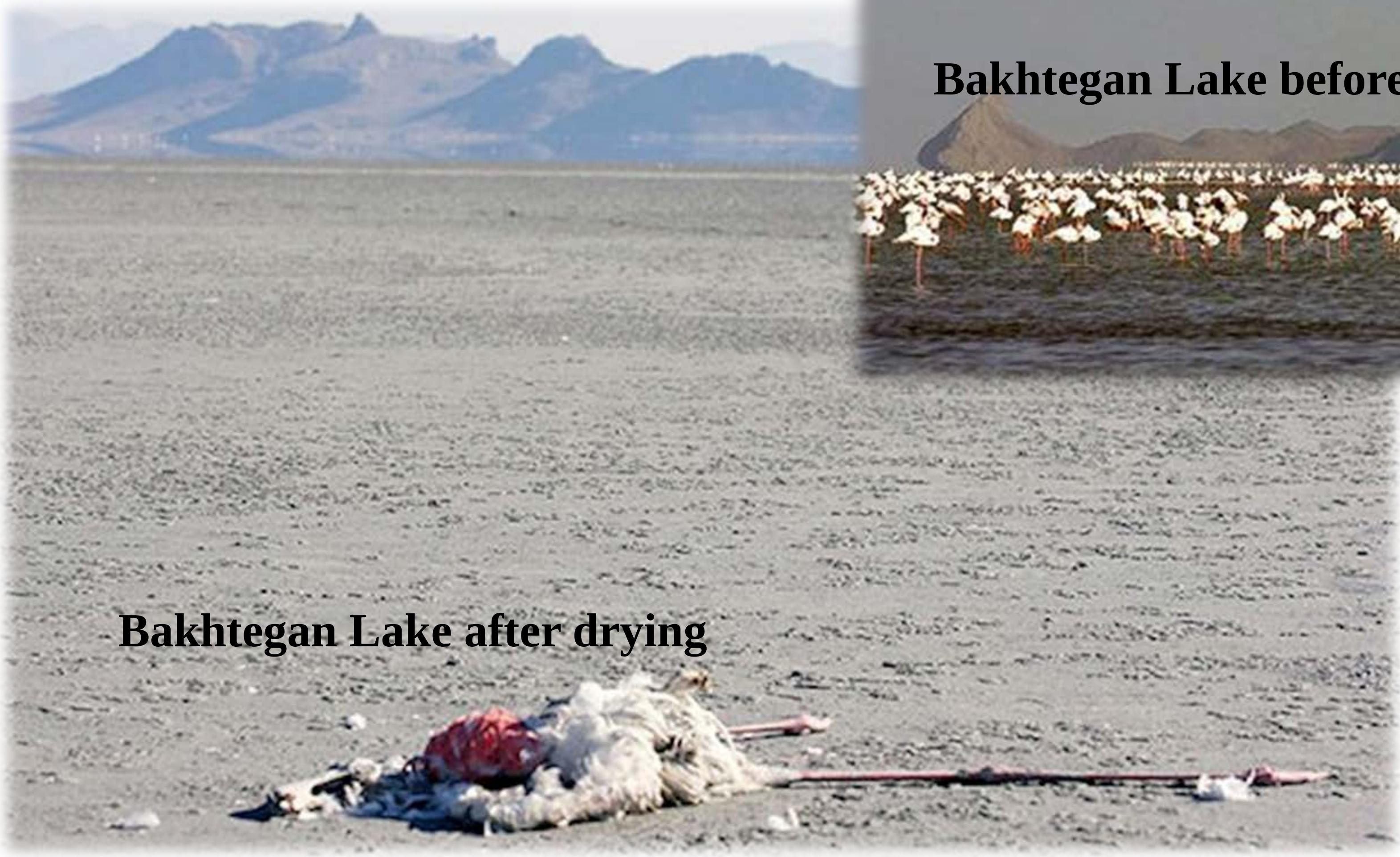
- ✓ Proposed modelling framework shows integrated simulation of the crop growth and basin hydrologic components can be used for basin wide water accounting.

- ✓ SWAT-FARS Package as a useful integrated DSS tool can help DM to better understand the current state of water resources, issues, future challenges and opportunities for improvements in the study area.

Thanks for your attention



Bakhtegan Lake before drying



Bakhtegan Lake after drying