Assessing the effectiveness of water-saving plans at the farm and basin level using agro-hydrological modeling and water accounting approaches

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1816 SGGW

Urmia lake

Area: 5,200 km²

Lake Urmia, Van and Sevan

200 km distance

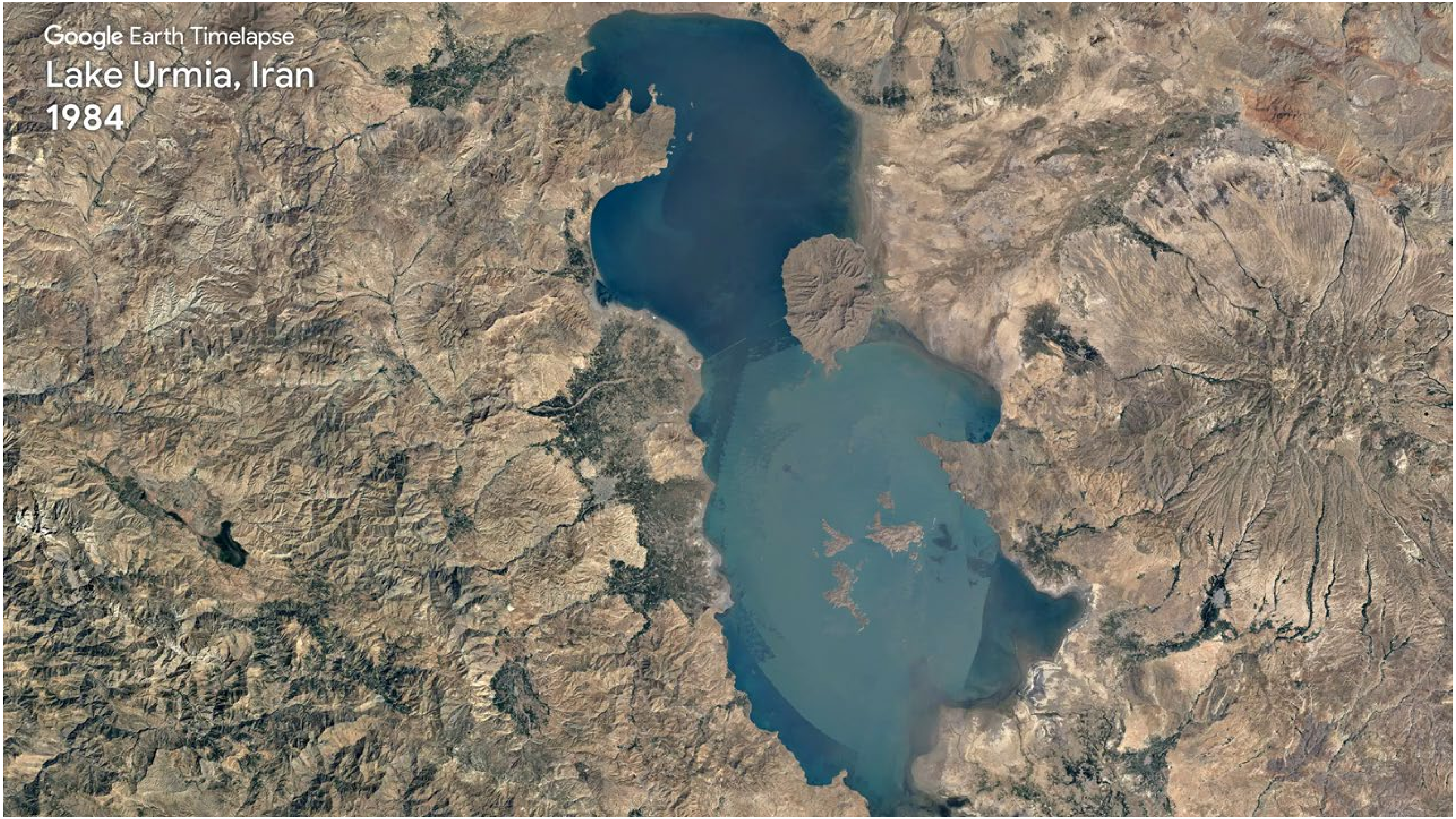
Climate change?

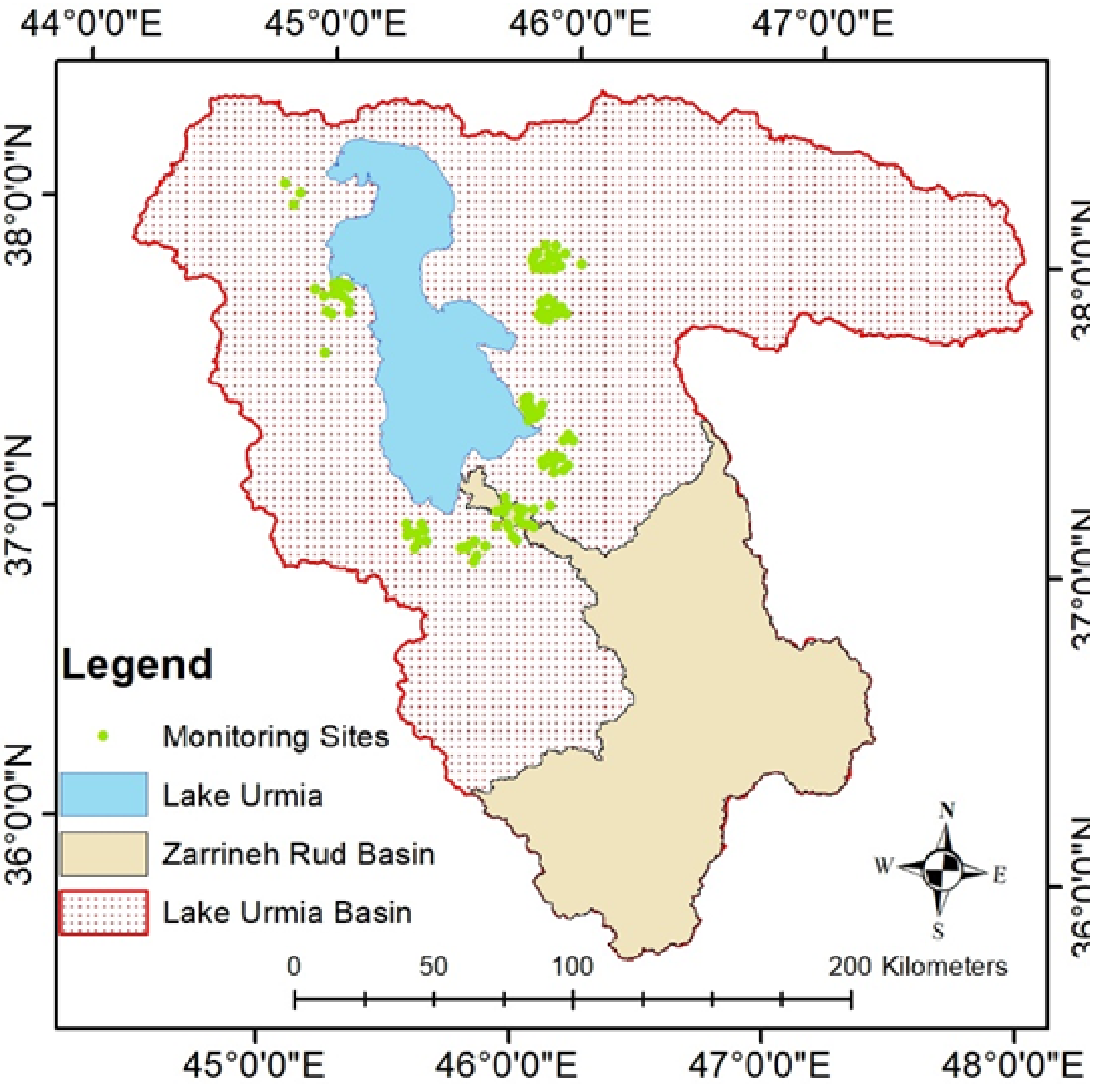
1995: 32 Bm^3 (maximum)

Now: 700 Mm^3

33 dams over 50 years

Agriculture

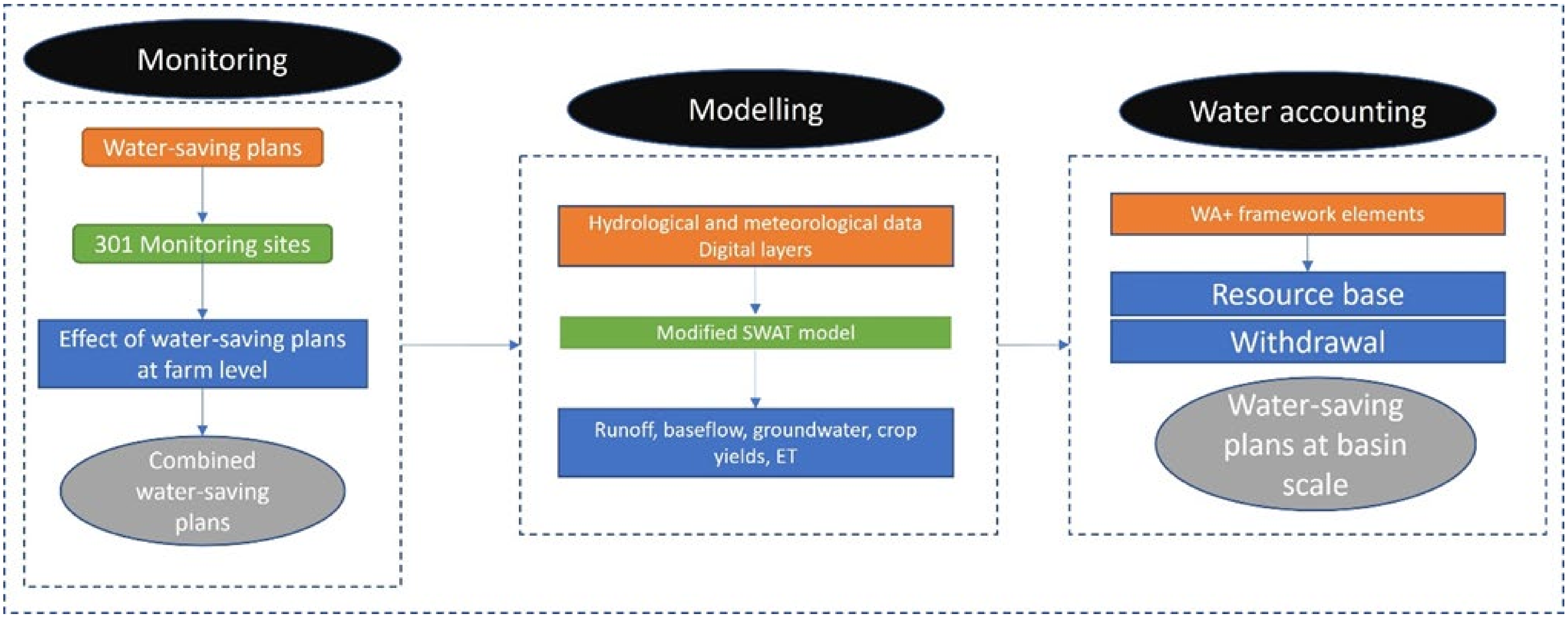

Google Earth Timelapse
Lake Urmia, Iran
1984



Study Area: Zarrineh Rud Basin

- The Zarrineh Rud Basin (ZRB), supplying more than **40% of total inflow water to Lake Urmia**, plays a vital role in its restoration plans, and could have a significant effect on the conservation of Lake Urmia.
- The basin covers an area of approximately **12,000 Sq-km**.
- Mean annual precipitation reaches approximately **400 mm**, and the most extended channel has a length of 300 km.
- More than **75,000 ha** of irrigated farms in ZRB produce a wide range of agricultural products, including potato, sugar beet, apple, barley, apple, and alfalfa.

Flowchart


Monitoring
Water-saving plans
301 Monitoring sites
Effect of water-saving plans at farm level
Combined water-saving plans
Modelling
Hydrological and meteorological data
Digital layers
Modified SWAT model
Runoff, baseflow, groundwater, crop yields, ET
Water accounting
WA+ framework elements
Resource base
Withdrawal
Water-saving plans at basin scale

Monitoring Sites at the Farm Level

Over a period of **4 years 301 farms** were monitored in the scope of a national project entitled “Local community participation in the restoration of Lake Urmia through the establishment of sustainable agriculture and biodiversity conservation”

Plan ID	Individual water-saving plan
I	Changes in irrigation management and developments in irrigation systems
II	Changes in fertilizer type and regime
III	Changes in the type and method of cultivation
IV	Farm size and shape adjustments

The monitoring aimed at the assessment of the effect of water-saving plans on the farmers' economy, crop yield increment, water resources, and changes in the lake’s water level.

The monitoring sites were designated in highly intense agricultural areas that use groundwater and surface water for irrigation.

Moreover, major crops of the Lake Urmia Basin are cultivated at these sites.

Corn, silage corn, barley, wheat, almond, apple, peach, potato, tomato, alfalfa, sugar beet, onion, and grape have the highest share in the cultivated areas of the sites

Agro-hydrological model configuration

- ZRB was divided into **110 subbasins**
- By employing two land use maps (2005 and 2015) and the FAO soil database, **1908 HRUs** were created
- According to the available datasets, management schedules were implemented in the model
- Period 1987-2015 was used for modeling, employing six weather and discharge stations (1987-2007 calibration period and 2008-2015 validation period)
- Zarrineh Rud dam characteristics were added to the SWAT model.

Water Accounting Plus (WA+) framework

Four categorized inventories of water balance information, namely resource base, evapotranspiration, withdrawal, and productivity.

The “Resource base” element delivers fundamental information on water balance components by considering the volume of precipitation, amount of ET, variations in water storage, outflow, and net withdrawals data.

The “Evapotranspiration” element mainly focuses on evaporation and transpiration. It permits the assessment of beneficial and non-beneficial water usage, anthropogenic influences in water consumption, and consumed water by land use.

The “Withdrawal” element covers a brief of water removals (from groundwater and surface), analyses of (non-) recoverable flow, and amount of water recycling.

The “Productivity” element employs agricultural products, consumptive application, and water efficiency to identify biomass yields, food security, and water yield. “Evapotranspiration” and “Productivity” elements are not included in the current study.

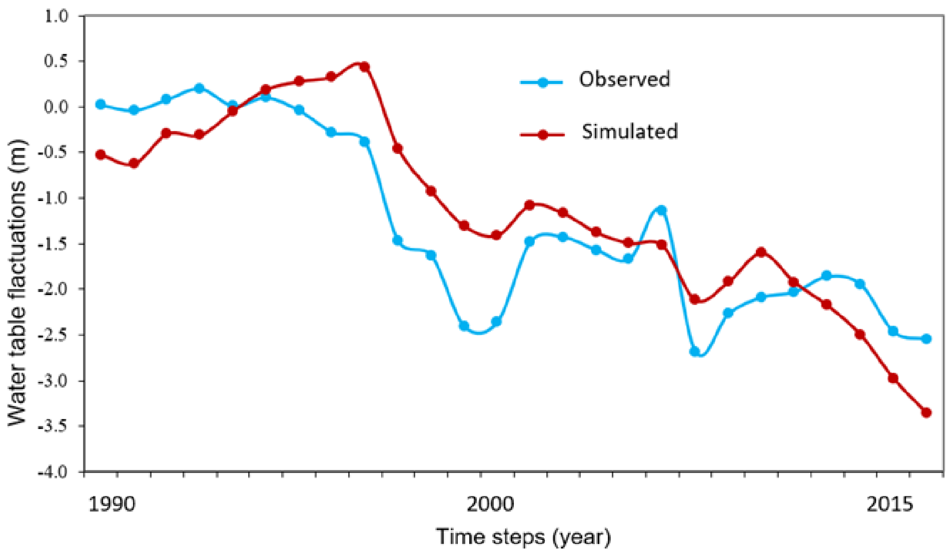
Results

Accuracy of the model in runoff and baseflow simulations

Discharge station		Monthly runoff				Baseflow	
		Calibration		Validation			
ID	Station	R^2	NSE	R^2	NSE	R^2	NSE
A	Nezamabad	0.87	0.67	0.86	0.64	-	-
B	Choubloche	0.77	0.63	0.61	0.41	-	-
C	Zarrinehrud	0.9	0.83	0.85	0.73	0.86	0.75
D	Safakhane	0.85	0.72	0.74	0.7	0.72	0.71
E	Poleanian	0.84	0.69	0.68	0.59	0.62	0.59
F	Senteh	0.83	0.71	0.82	0.65	0.74	0.69

Name, unit, initial range, and finale ranges of calibrated parameters in runoff simulation

Parameter	Unit	Description	Initial range	Final range
CN2	-	SCS runoff curve number f	40 - 90	53 - 79
PLAPS	*mm/Km/yr*	Precipitation lapse rate	-0.2 – 0.2	-0.03 – 0.18
GW_DELAY	*day*	Groundwater delay	1 - 60	12 - 47
GWQMN	*mm*	Threshold depth of water in the shallow aquifer required for return flow to occur	100 - 2000	650 - 1250
RCHRG_DP	-	Deep aquifer percolation fraction	0 – 0.9	0.03 – 0.82
SOL_AWC	$\frac{mm\ H_2O}{mm\ Soil}$	Available water capacity of the soil layer	-0.5 – 0.5	-0.22 – 0.37
SOL_K	*mm/h*	Saturated hydraulic conductivity	-0.5 – 0.5	-0.11 – 0.24
ALPHA_BF	*1/day*	Baseflow alpha factor (days)	0.01 - 1	0.04 – 0.42
SOL_Z	*mm*	Depth from soil surface to bottom of layer	-0.5 – 0.5	-0.32 – 0.05
TLAPS	$^oC/Km$	Temperature lapse rate	(-8) – (-5)	(-7.5) – (-5.5)
REVAPMN	*mm*	Threshold depth of water in the shallow aquifer for "revap" to occur	100 - 2000	700 - 1300
GW_REVAP	-	Groundwater "revap" coefficient	0 – 0.2	0.01 – 0.07
SMTMP	^oC	Snow melt base temperature	-0.5 - 3	1.75
SFTMP	^oC	Snowfall temperature	-0.5 - 3	-0.23



Observed and simulated groundwater water table fluctuations

Results – crop yields and ET

Accuracy of model in crop yield and ET simulations for different crops

Variable	Index	Wheat	Barley	Potatoes	Tomatoes	Sugar beet	Alfalfa	Apple
ET	R^2	0.5	0.79	0.94	0.89	0.92	0.79	0.98
	NSE	0.67	0.47	0.94	0.34	0.92	0.47	0.98
Crop yield	R^2	0.66	0.83	0.62	0.48	0.6	0.83	0.92
	NSE	0.27	0.35	0.47	0.51	0.61	0.35	0.92

Average of crop yields (tons/ha) and ET (mm) for different crops

Crop	Crop yield (tons/ha)		ET (mm)	
	Model	Observed	Model	Observed
Wheat	3.46	3.46	379	382
Barley	2.6	2.69	312.9	303
Potatoes	21.7	21.17	606.7	618
Tomatoes	31.7	33.03	574.5	572
Sugar beet	42.65	44.6	678.7	696
Alfalfa	8.5	8.5	762	773
Apple	23.66	22.14	687.6	702

The List of selected parameters in crop yield and ET calibration process

Parameter	Parameter description	Sugar beet	Tomatoes	Apple	Alfalfa	Potatoes	Wheat	Barley
BLAI	Max leaf area index	15	15	9.5	10	10	3.5	4
DLAI	Fraction of growing season when leaf area begins to decline	1	1	0.99	0.99	1	0.8	0.5
HVSTI	Harvest index	2.4	1	1	0.67	1.25	0.4	0.6
FRGRW1	Fraction of the growing season corresponding to the 1st point on optimal leaf area	0.01	0.05	0.03	0.05	0.05	0.1	0.25
FRGRW2	Fraction of the growing season corresponding to the 2nd point on optimal leaf area	0.1	0.1	0.99	0.4	0.25	0.05	0.95
LAIMX1	Fraction of maximum leaf area index corresponding to the 1st point on optimal leaf area development curve	0.8	0.9	0.7	0.05	0.1	0.05	0.01
LAIMX2	Fraction of maximum leaf area index corresponding to the 2nd point on optimal leaf area development curve	0.99	0.4	0.95	0.95	0.95	0.95	0.85
BIO_E	Biomass/Energy Ratio	100	100	40	36	110	55	90
T_OPT	Optimal temp for plant growth	25	24	20	20	24	20	20
T_BASE	Min temp plant growth	3	8	4	3	6	0	0

Results – Scenario simulations

The changes in the strategy (such as irrigation systems) and resulting change in land and water productivity

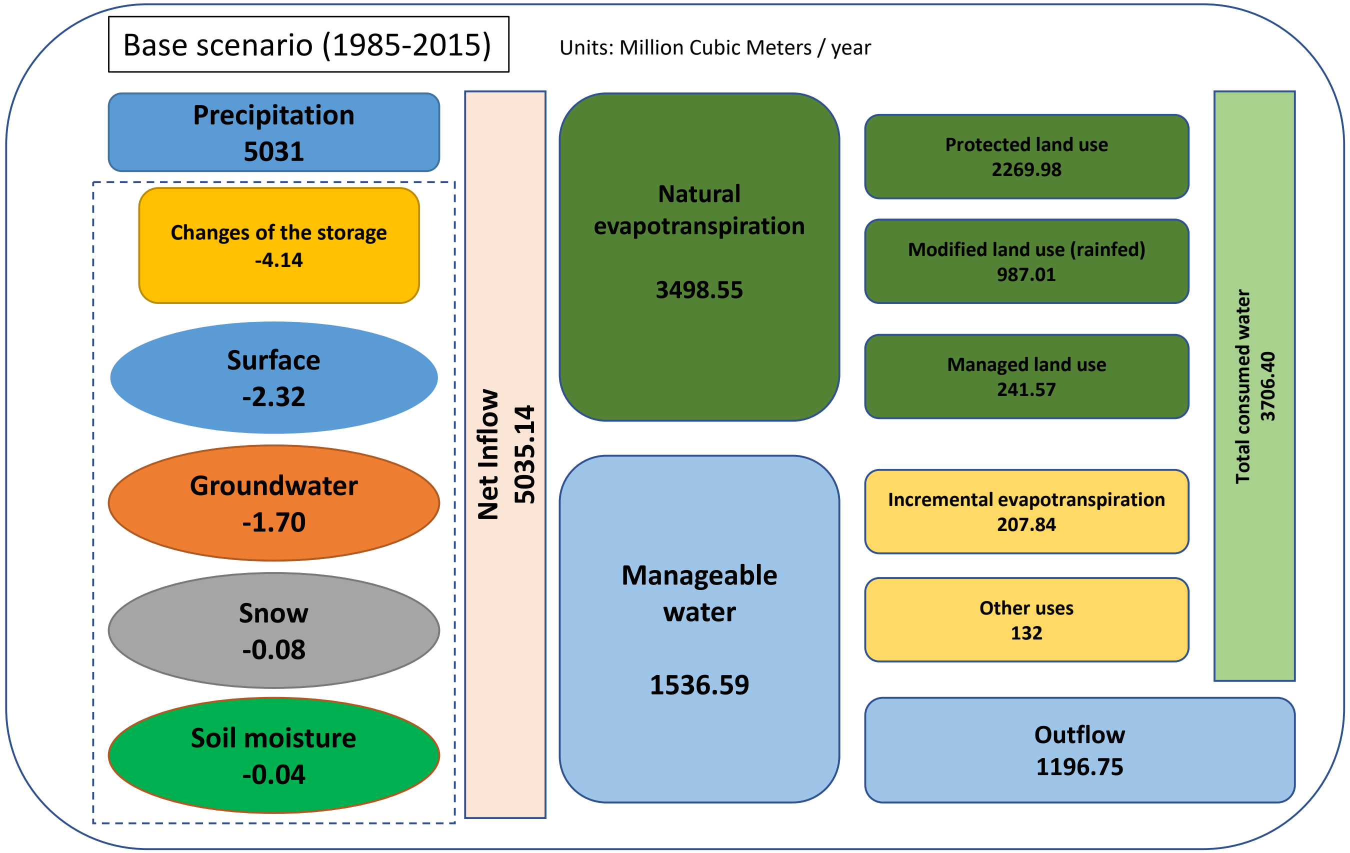
Plan ID*	**Individual water-saving plan**	**Water withdrawal (m^3/ha)**	**Water usage (m^3/ha)**	**Crop yield (tons/ha)**	**Water productivity (kg/m^3)**
I	Changes in irrigation management and developments in irrigation systems	-6636	-1874	4	5
II	Changes in fertilizer type and regime	2410	-2366	2	0
III	Changes in the type and method of cultivation	-4469	-1288	3	2
IV	Farm size and shape adjustments	-2928	-1427	0	1

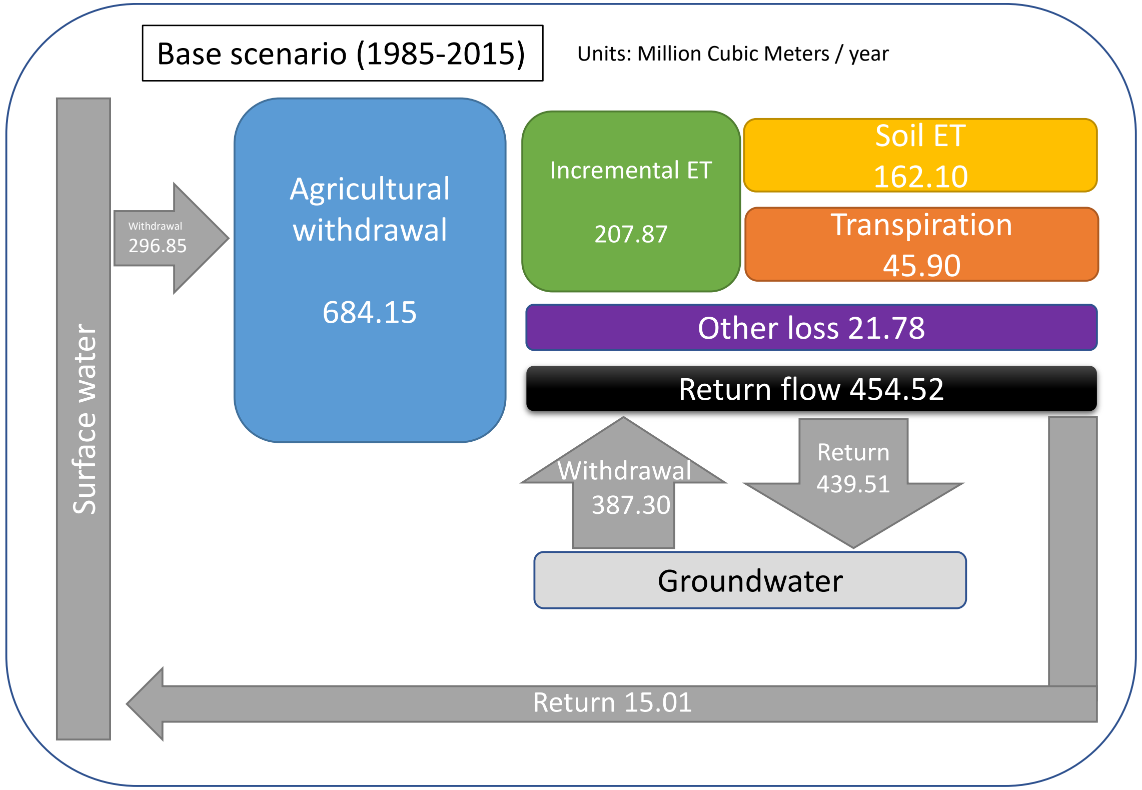
Effect of combined water-saving plans based on model outputs

ID	**Combined plan (based on individual plans' ID)**	**Saved water (10^3 m^3)**	**Changes in lake inflow (10^3 m^3)**	**Changes in groundwater resources (10^3 m^3)**
A	I, II, III, IV	-343	-230	-2
B	I, III, IV	-6453	-6473	-3
C	**I, IV**	**25860**	**25889**	**-247**
D	**II, III, IV**	**9489**	**9526**	**3**
E	I	-988	-994	-2
F	II, IV	3036	3160	19
G	I, II, III	-980	-998	-2

Water Accounting Plus (WA+) framework

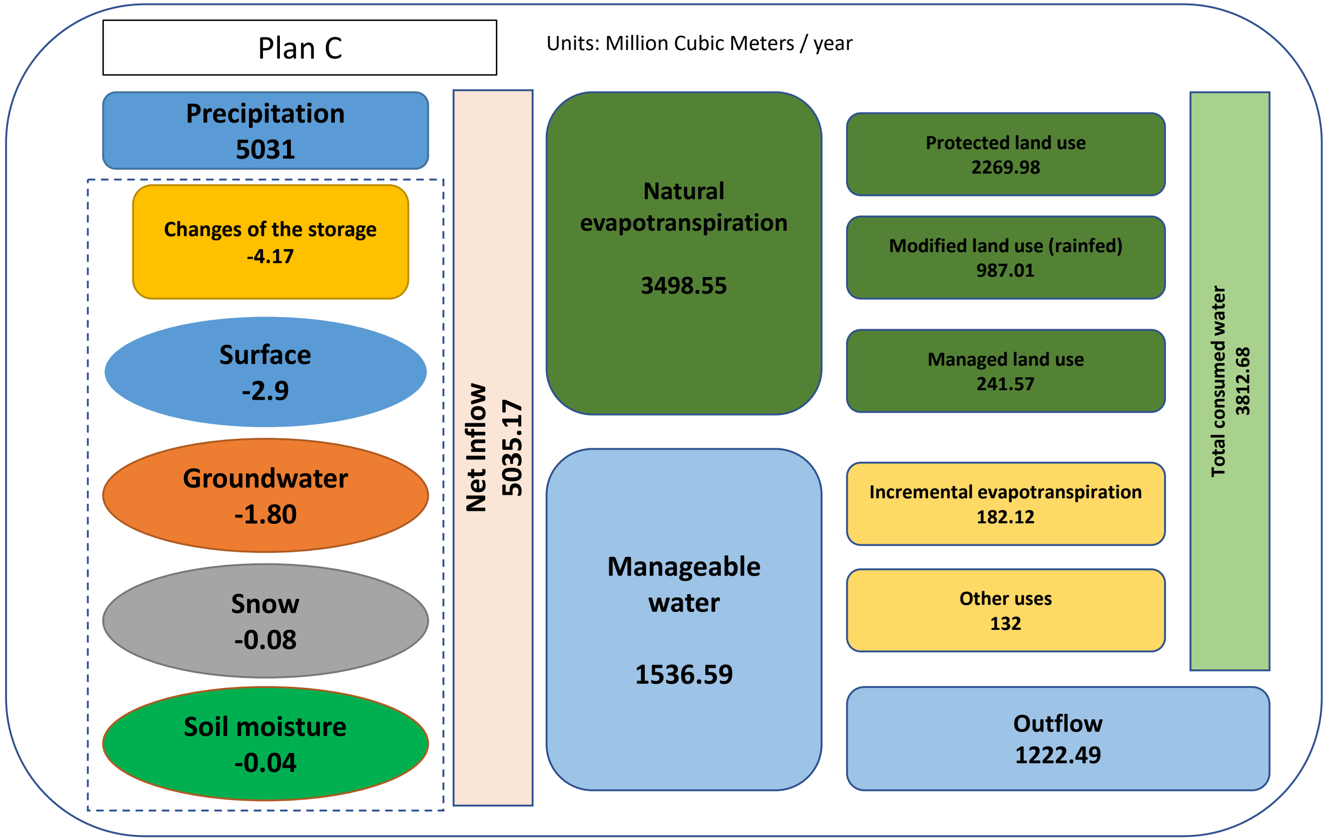
Base scenario (status quo)

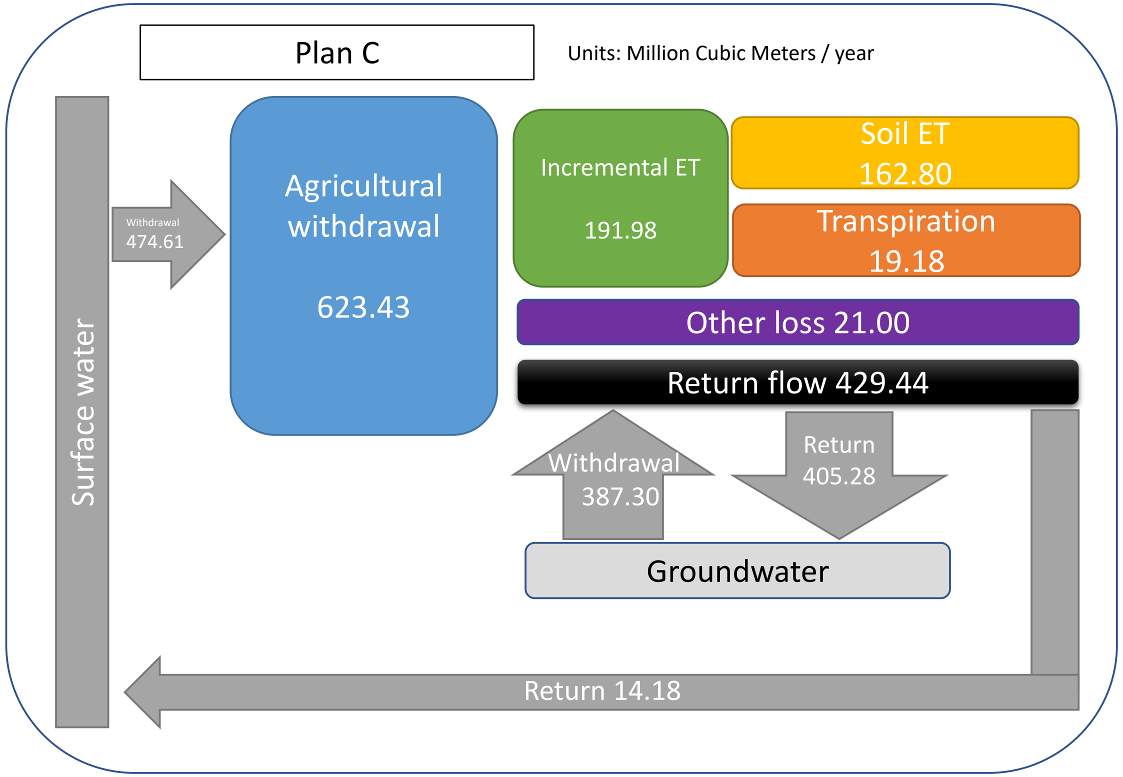




Water Accounting Plus (WA+) framework

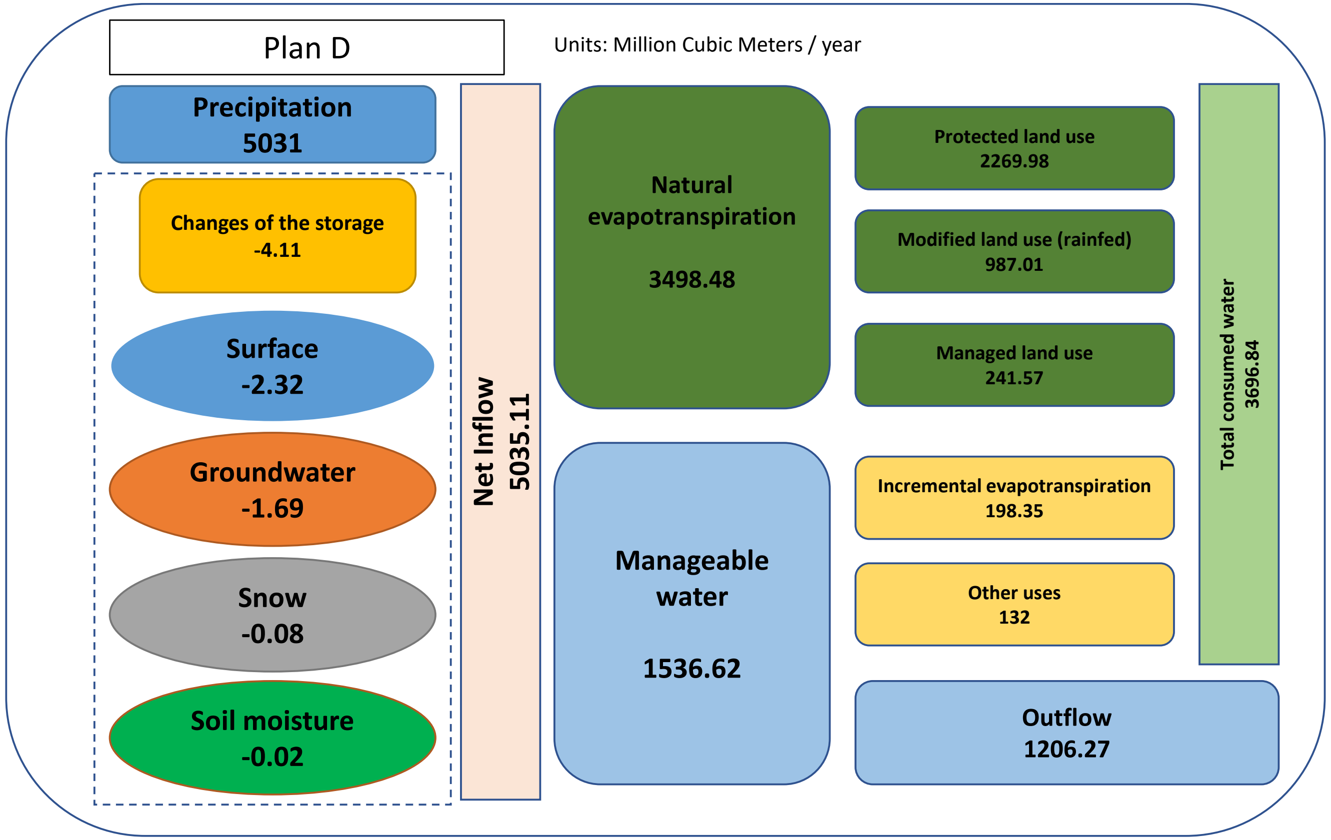
Scenario (Plan C)

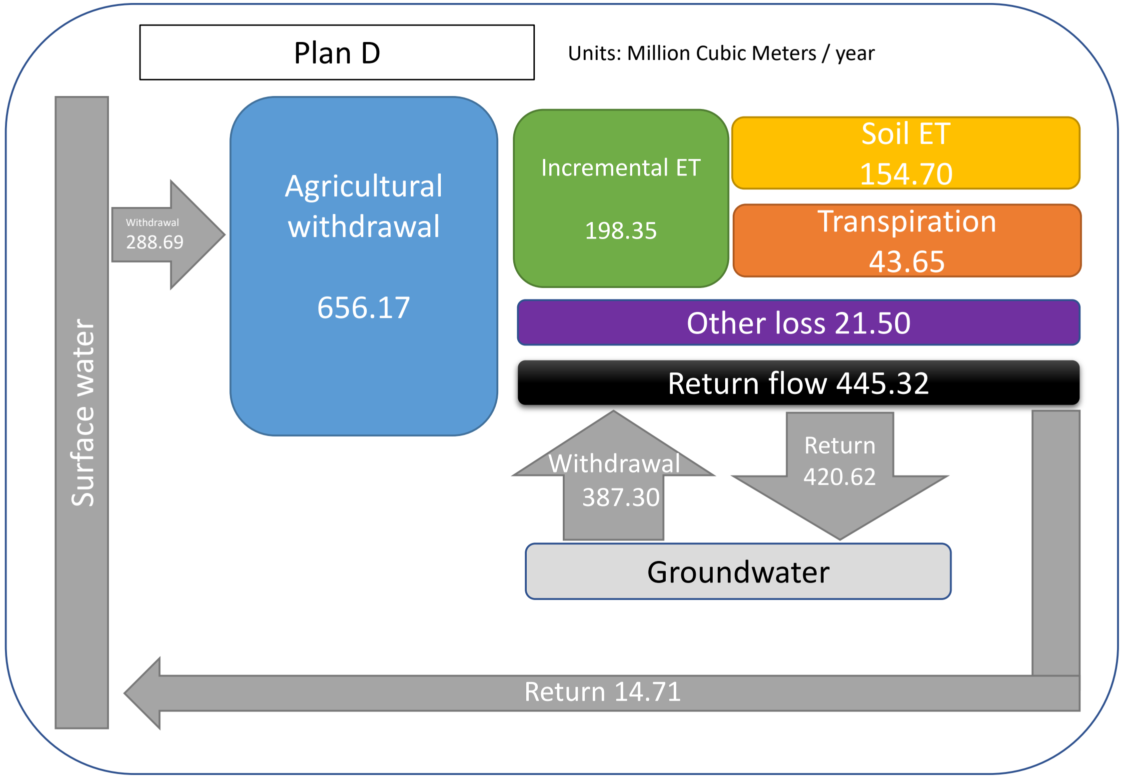




Water Accounting Plus (WA+) framework

Scenario (Plan D)





Conclusion

* **Changes in irrigation management and developments in irrigation systems had the greatest impact on reducing water removal and could reduce ET.**
* **Changes in fertilizer type and regime did not significantly impact accessible water supplies.**
* **Variations in ET showed a wide range of effects of water-saving plans, with an increase due to changes in fertilizer type and regime.**
* **The most significant achievements in water-saving actions were increased crop yield and water productivity. Under the changes in irrigation management and developments in irrigation systems plan, crop yields increased by an average of four tons/ha and water productivity increased by around five kg/m3.**
* **Seven combined water-saving strategies were designed and applied over ZRB using the modified SWAT model. Three plans that increased runoff had better impacts on Lake Urmia and two of the best plans were selected for implementation into the model and WA+ assessment.**

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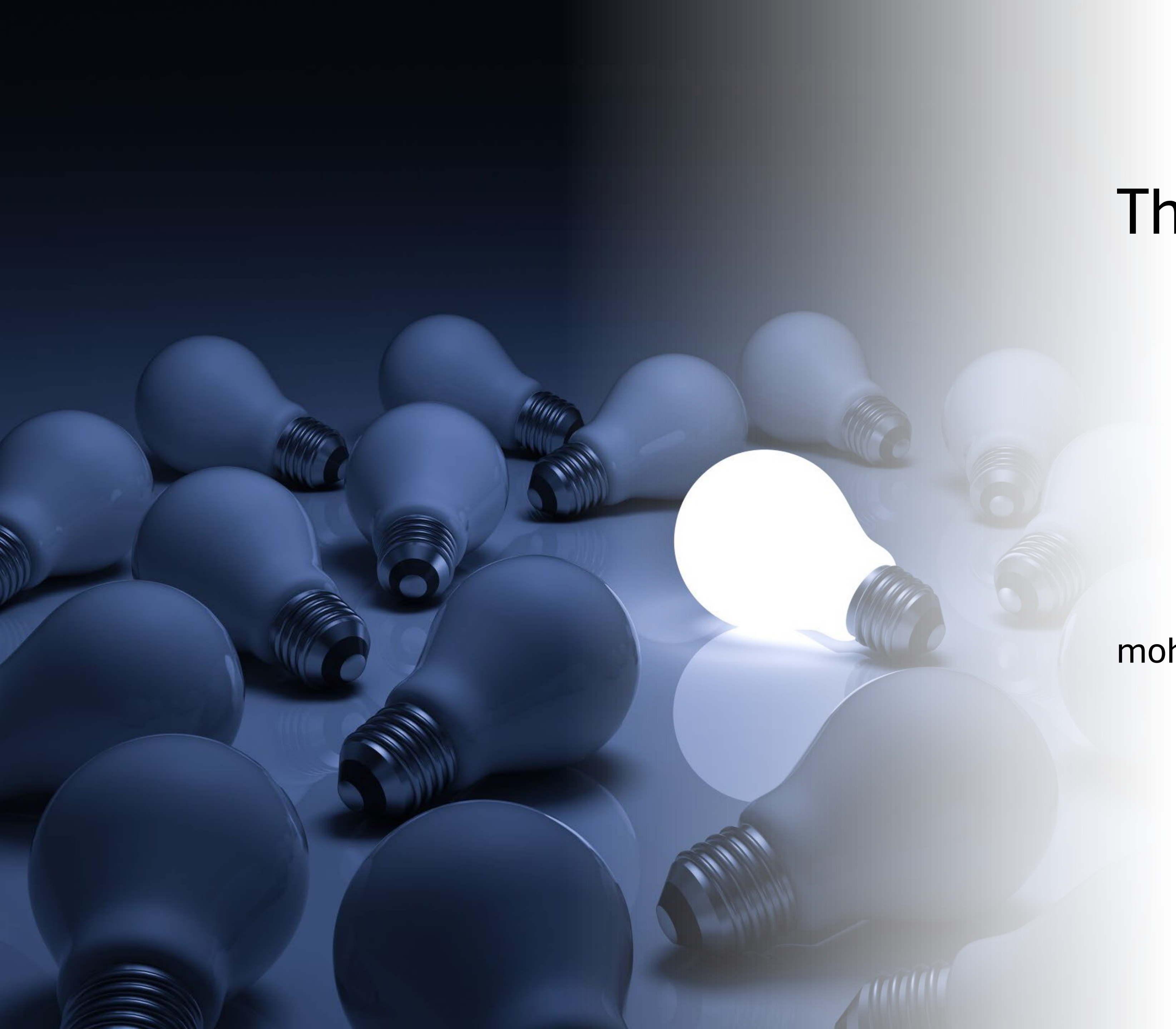

Thanks for your attention!

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