Coupling Hydrologic and Water Allocation Models for Basin Scale Water Resources Management Considering Crop Pattern Changes

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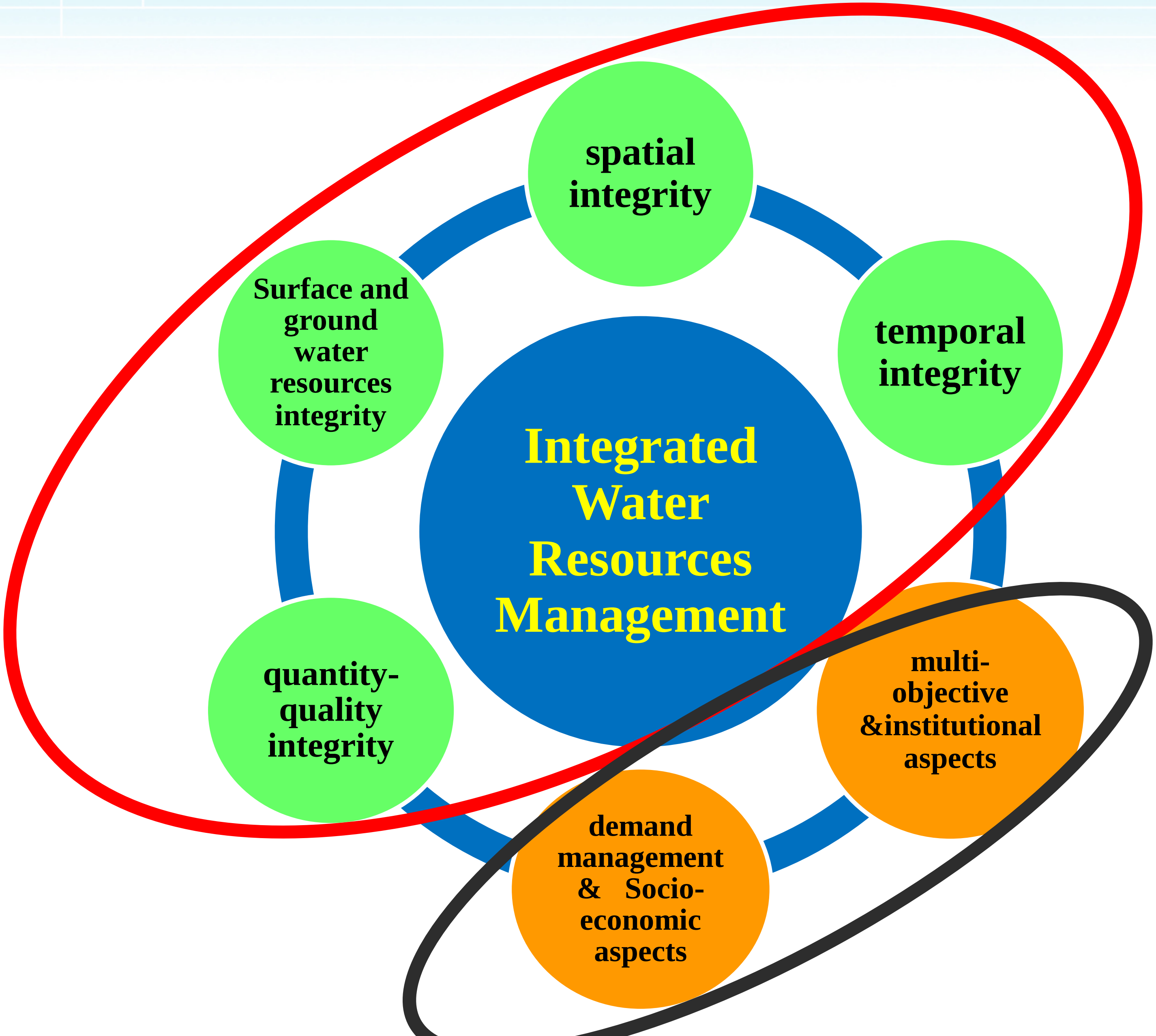
Introduction

Basin-scale management requires advanced forecasts of the water availability and optimal allocation of water to competitive demands.

Water Availability: Hydrologic Models (SWAT,…)

Water Allocation: Decision Support Systems (MODSIM, WEAP, Mike Basin, …)

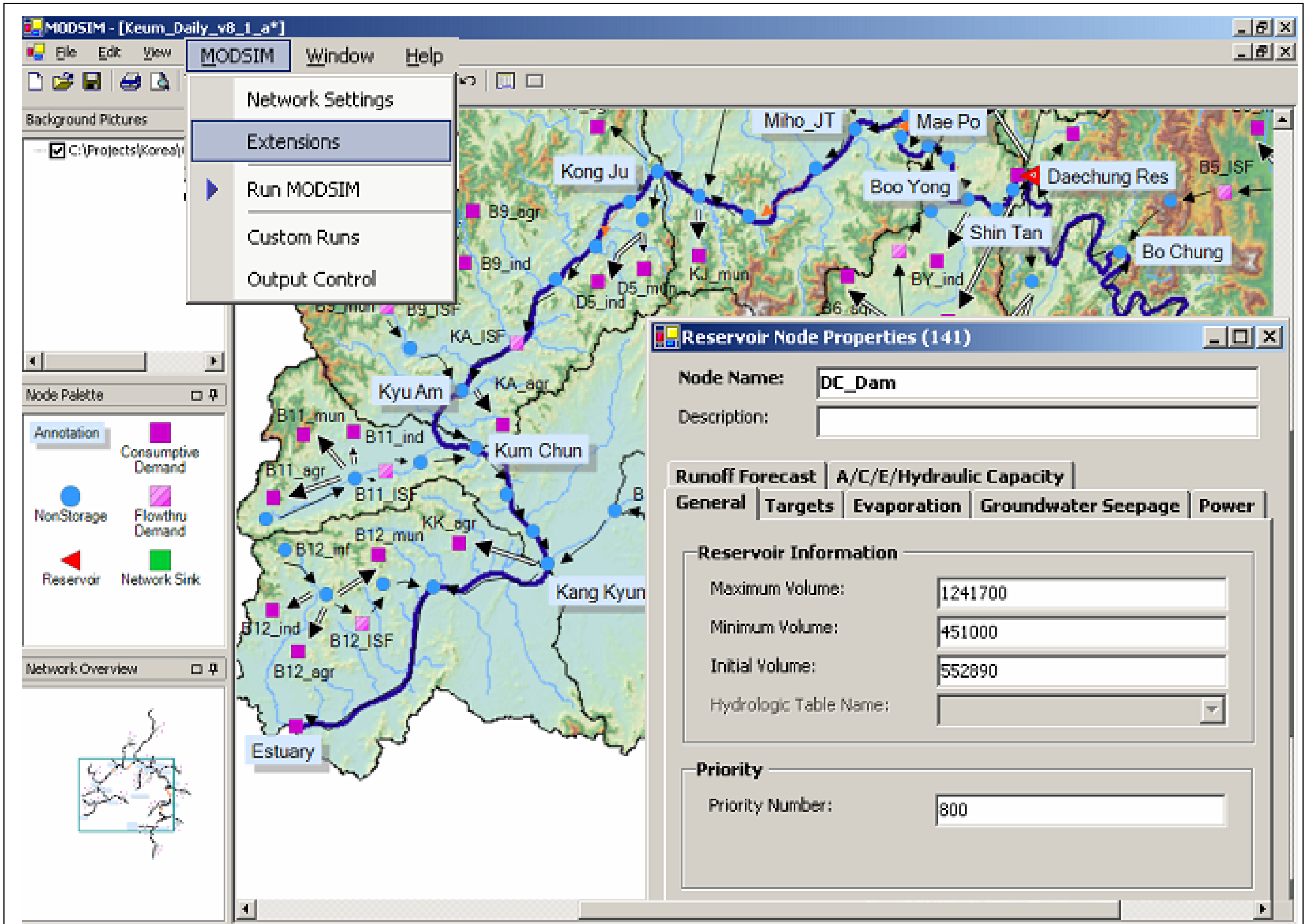
Integrated Water Resources Management


spatial integrity
Surface and ground water resources integrity
temporal integrity
Integrated Water Resources Management
quantity-quality integrity
multi-objective &institutional aspects
demand management & Socio-economic aspects

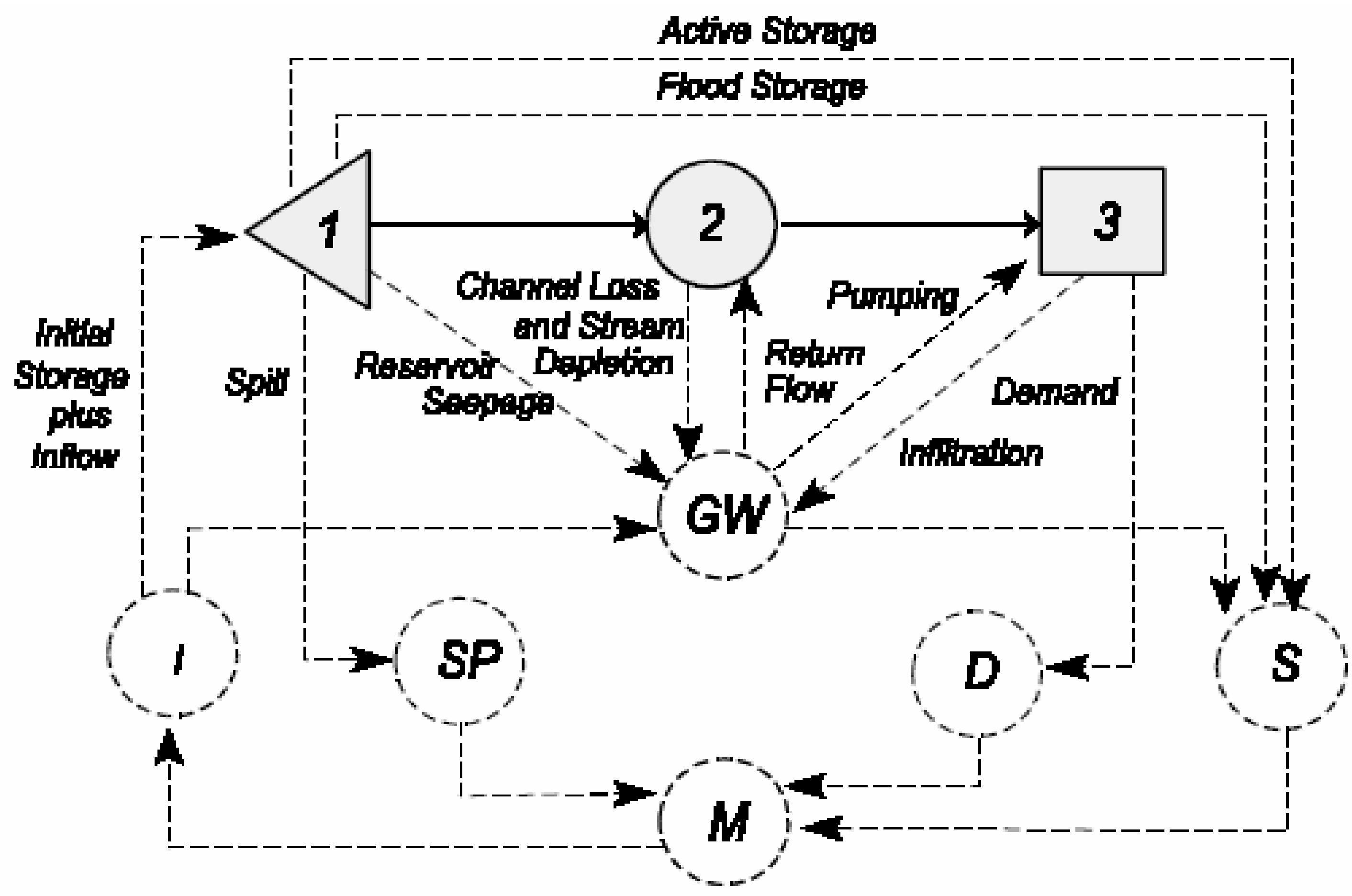
Decision Makers need knowledge of both water availability and optimal water allocation.

MODSIM

MODSIM, a generalized river basin network flow model, developed in Colorado state University in the mid-1970



Network Structure of MODSIM



MODSIM

MODSIM **sequentially** solves the following optimization problem to optimize the allocation between different users

$$Minimize \sum_{l \in A} c_l q_l$$

Subject to:

$$\sum_{j \in O_i} q_j - \sum_{k \in I_i} q_k = 0; \quad \text{for all i} \in \text{N}$$

$$l_l \leq q_l \leq u_l; \quad for\ all\ l \in A$$

We used Particle Swarm Optimization algorithm to allocate water to different demand sectors in the **entire simulation period** instead of month by month

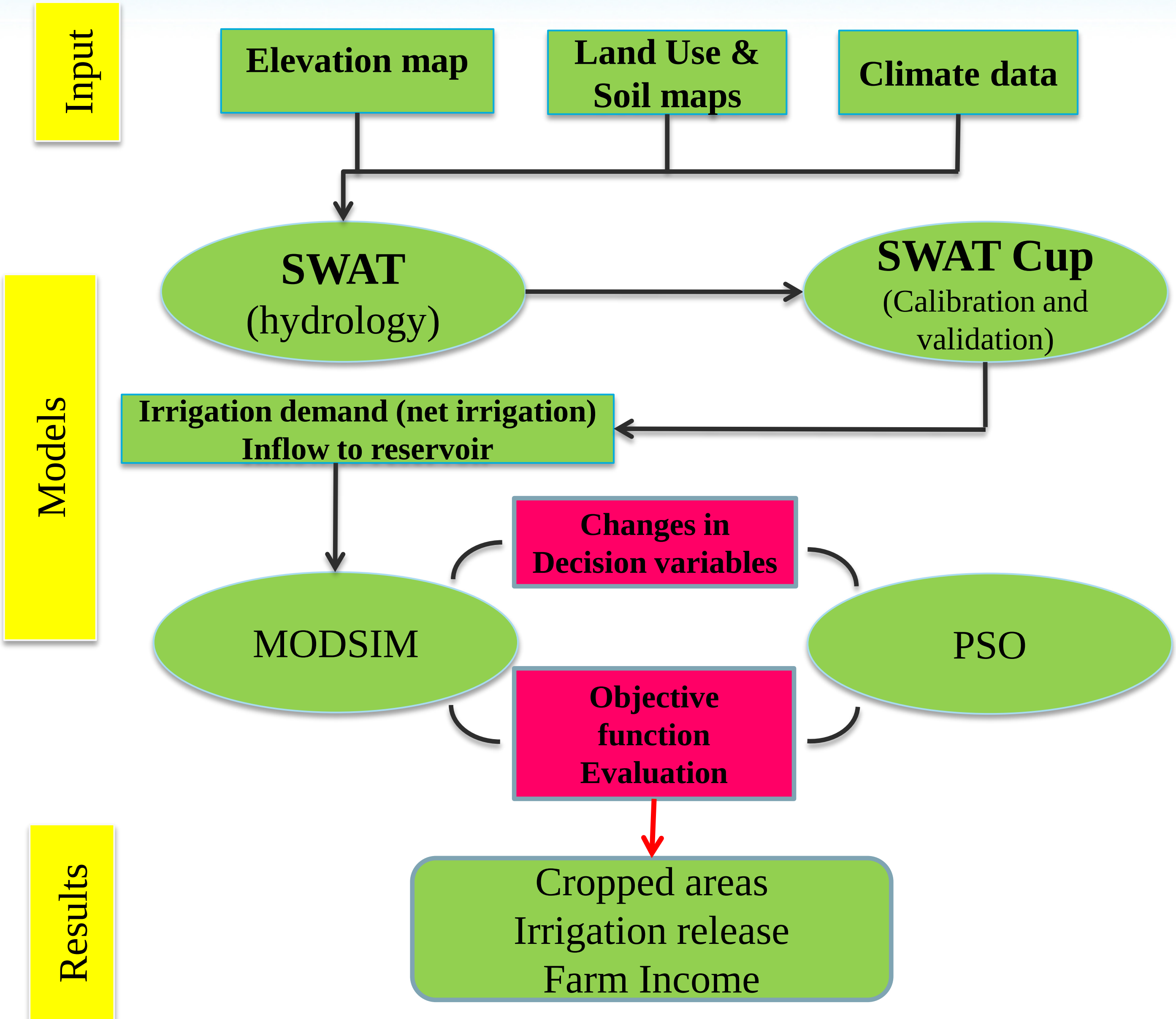
Particle Swarm Optimization (PSO)

PSO is a stochastic population-based optimization approach, first proposed by Kennedy and Eberhart (1995)

It facilitates simple rules to simulate bird flocking

PSO is an optimizer for nonlinear functions

Flowchart of the SWAT-MODSIM -PSO



Study Area

Karkheh River Basin (KRB)

KRB

Location:
South west of Iran, Middle East, Asia

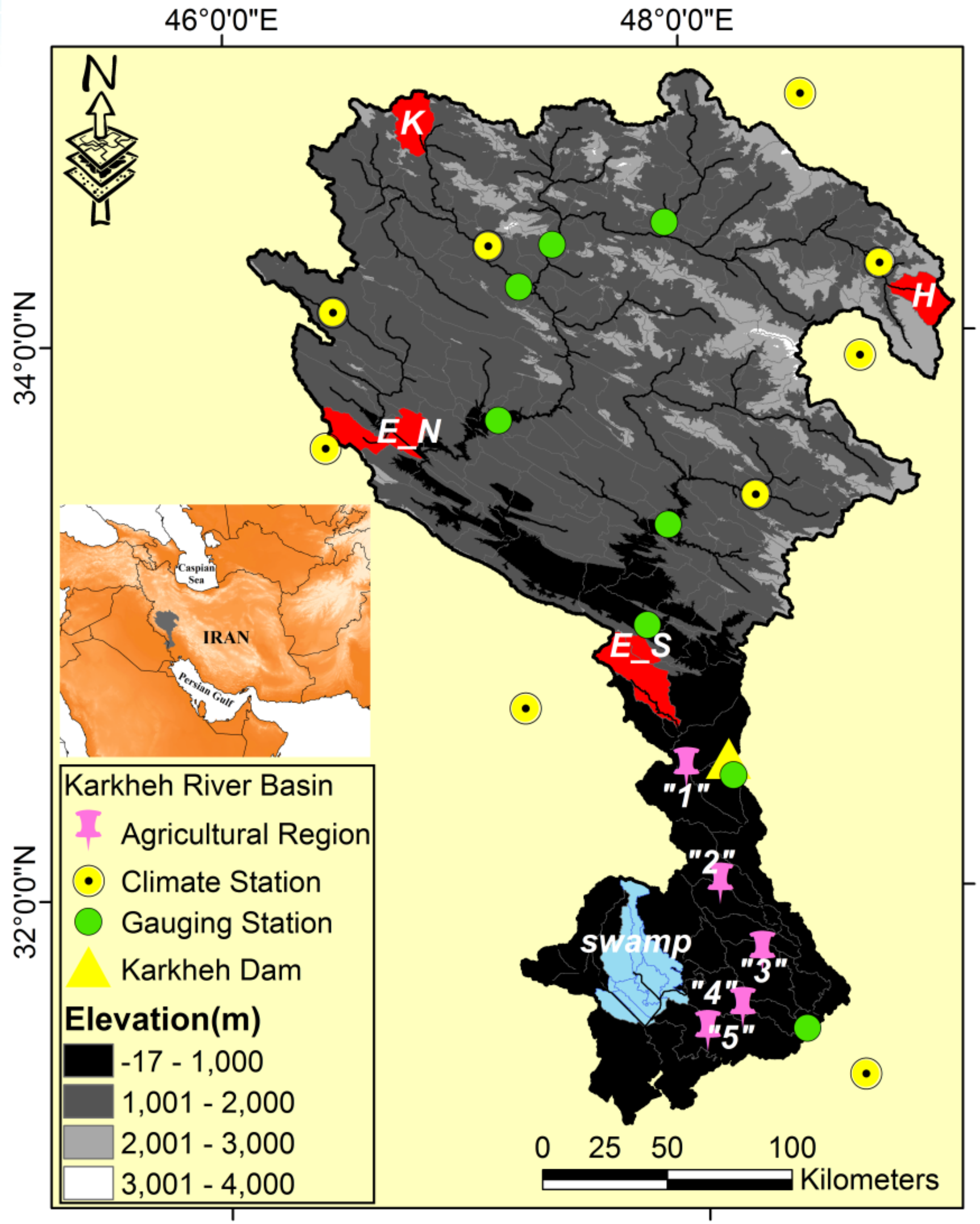
Area: 51000 km^2

Climate: Semi Arid

Food Basket of Iran

1.Covers 9% of Iran's irrigated area
2. Produces 10–11% of the country's wheat

SWAT, SWAT-CUP



Area: 51000 km^2

Dem: 90 m
Soil: 1 km (FAO, 1995),
Land use: 900 m

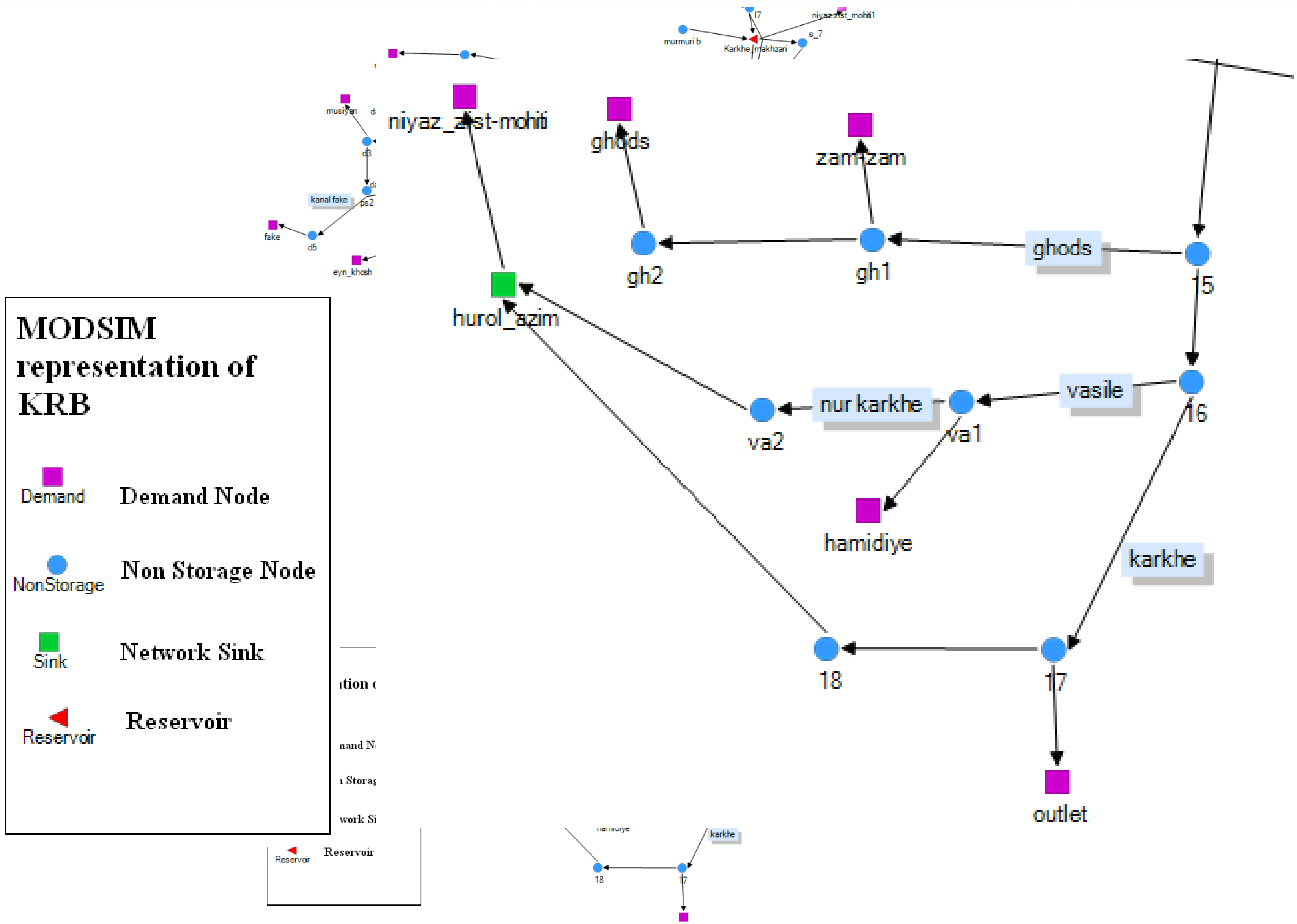
Gauging station: 8
Climate Station: 9

Karkheh Dam's operation start from 2000

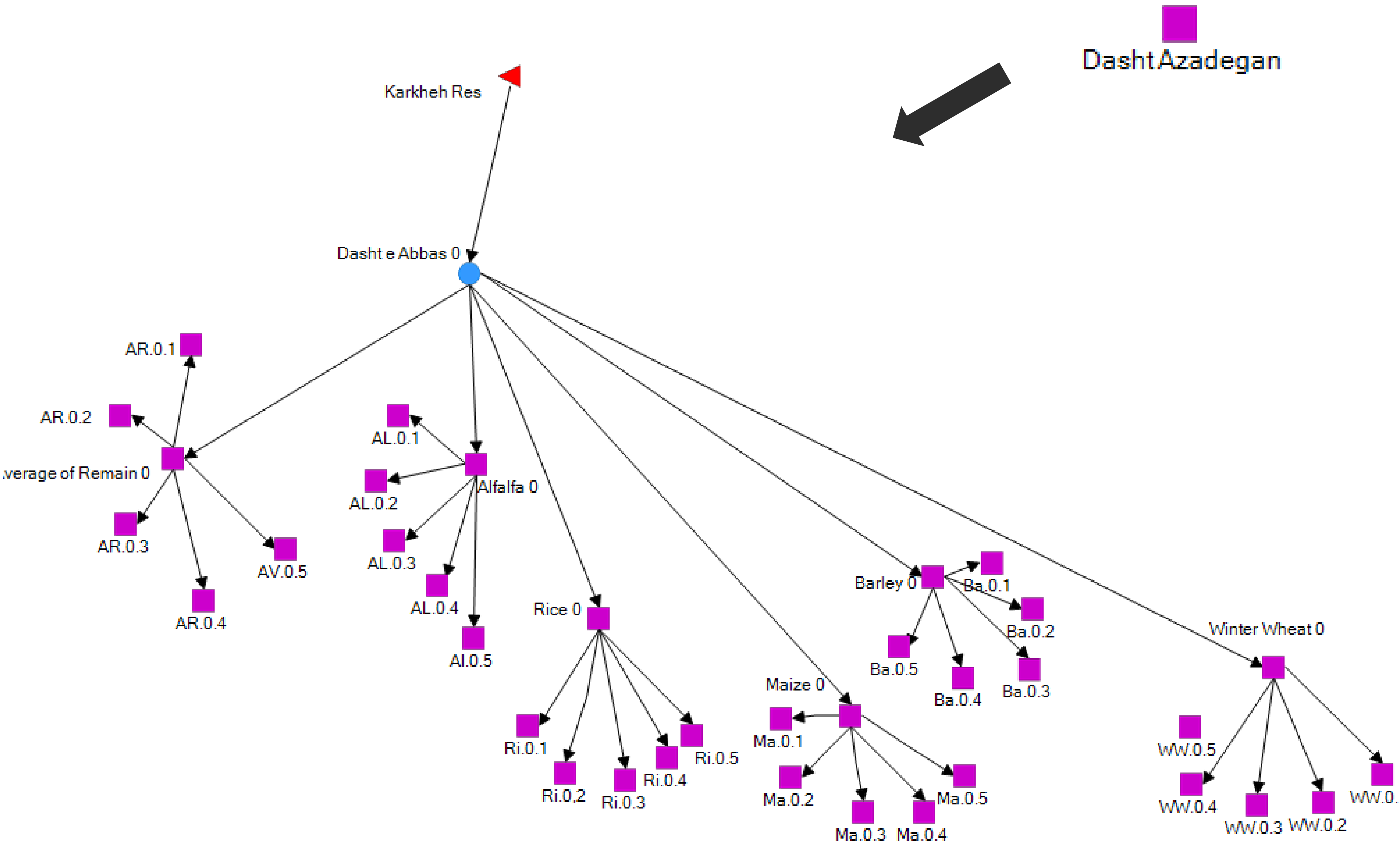
Calibration:
1987-2005

validation:
1982-1987

Representation of KRB in MODSIM



MODSIM Adaptation to SWAT



Objective Function

$$Income = \max_{A_i, R_{ij}} \sum_{i=1}^{n} [P_i (Y_a)_i - (F_i + V_i)] A_i$$

Where:
Income = Total farm income($),
P = product price ($ kg^{-1}),
R_{ij} = reservoir release to cropped area *i* in time *j*,
Y = yield (kg)
A = cropped area (ha),
F= fixed cost
V= variable cost
2 main constraint :Maximum and minimum area of each agricultural land and reservoir balance:

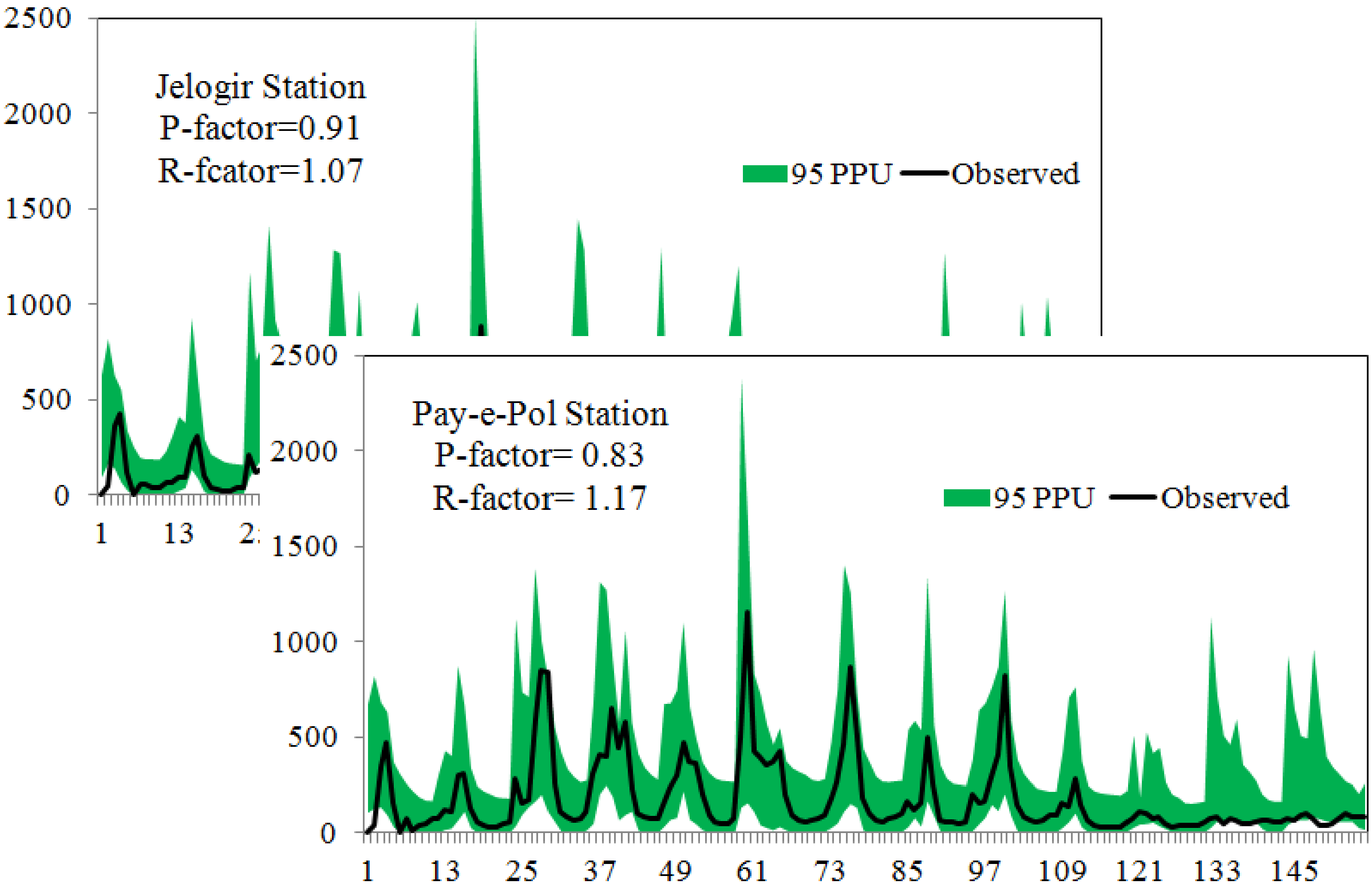
$$S_{j+1} = S_j + Q_j - \sum_{i=1}^{n} 10 A_i R_{i,j} - 0.001 E_i f(S_j) - SP_j + RAIN_j$$

3 scenarios modeled in this study

Scenarios	Conditions	Description
S1	Constraints: $0.6\ A_T \leq A_{wheat} + A_{rice} + A_{maize} + A_{barley} \leq 0.75\ A_T$	Continuing the historic trend
S2	Constraints: $0.35\ A_T \leq A_{wheat} + A_{rice} + A_{maize} + A_{barley} \leq 0.\ 5 \times A_T$	Limit the grain areas to less than 50%
S3	Constraints: $A_0 \leq A_{wheat} + A_{rice} + A_{maize} + A_{barley} + A_{other} \leq A_T$	No limitation

Results

SWAT & SWAT-CUP



Materials and Methods

Calibration and Validation of SWAT

Gauging Station	Calibration		Validation	
	P-factor	R-factor	P-factor	R-factor
Aran	0.75	1.02	0.78	1.19
Polchehr	0.75	1.04	0.89	1.24
Ghurbagh	0.84	0.89	0.88	1.11
Huliyan	0.92	1.08	0.94	1.23
Afarine	0.92	1.2	0.71	1.28
Jelogir	0.91	1.05	0.89	1.13
Pay-e-Pol	0.83	1.17	0.82	1.24
Hamidiyeh	0.89	1.42	0.97	1.73

Results

Changing in Crop Pattern for Different Scenarios

	Dashte Abbas & Avan					
Scenarios	**Wheat**(%)	**Maize**(%)	**Rice**(%)	**Barley**(%)	**Other Crops**(%)	**Income**($)
Historic	**52.6**	**17.7**	**6.8**	**4.7**	**18.2**	27×10^6
S1	**52**	**15**	**3**	**5**	**25**	25.5×10^6
S2	**35**	**20**	**2**	**6**	**37**	30×10^6
S3	**25**	**29**	**2**	**4**	**40**	35×10^6

	Dolsagh					
Scenarios	**Wheat**(%)	**Maize**(%)	**Rice**(%)	**Barley**(%)	**Other Crops**(%)	**Income**($)
Historic	**58.6**	**22.8**	**0**	**0**	**18.6**	12.6×10^6
S1	**60**	**13**	**0**	**3**	**2**	11.9×10^6
S2	**30**	**33**	**0**	**2**	**35**	16.8×10^6
S3	**41**	**23**	**0**	**0**	**46**	14×10^6

Results

Changes in Crop Pattern for Different Scenarios

	Arayez & Bagheh					
Scenarios	Wheat(%)	Maize(%)	Rice(%)	Barley(%)	Other Crops(%)	Income($)
Historic	55.3	14.3	9.1	3.3	18	21.6×10^6
S1	52	15	2	6	25	20.4×10^6
S2	42	7	3	5	43	24×10^6
S3	39	7	0	2	52	28.8×10^6

	Hamidiyeh & Ghods					
Scenarios	Wheat(%)	Maize(%)	Rice(%)	Barley(%)	Other Crops(%)	Income($)
Historic	75.3	0.1	5.9	7.7	12	16.2×10^6
S1	66	4	0	5	25	15.3×10^6
S2	39	12	0	3	46	18×10^6
S3	33	17	0	2	48	21.6×10^6

Thank you for your attention