Hydro Predict'2012

Graduate Institute of Bioenvironmental Systems Engineering National Taiwan University

Intelligent water allocation strategy: a case study in northern Taiwan

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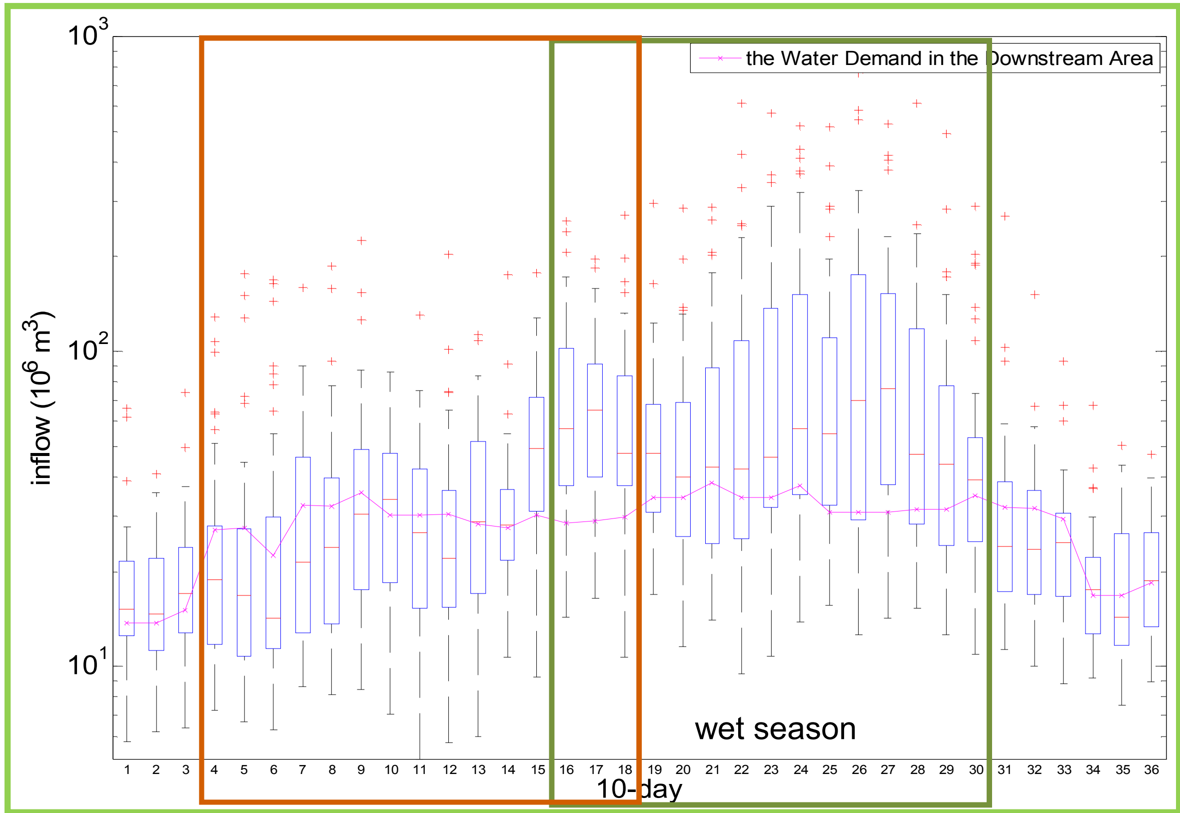
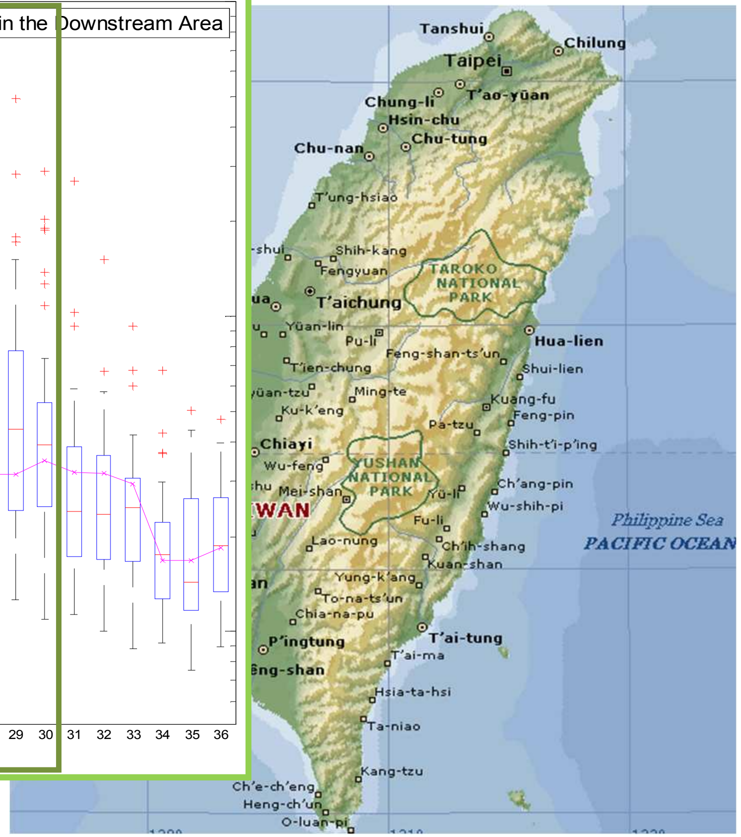
Background

Background

- non-uniform distribution of water resources





- **Public water** has a higher priority to **irrigation water**

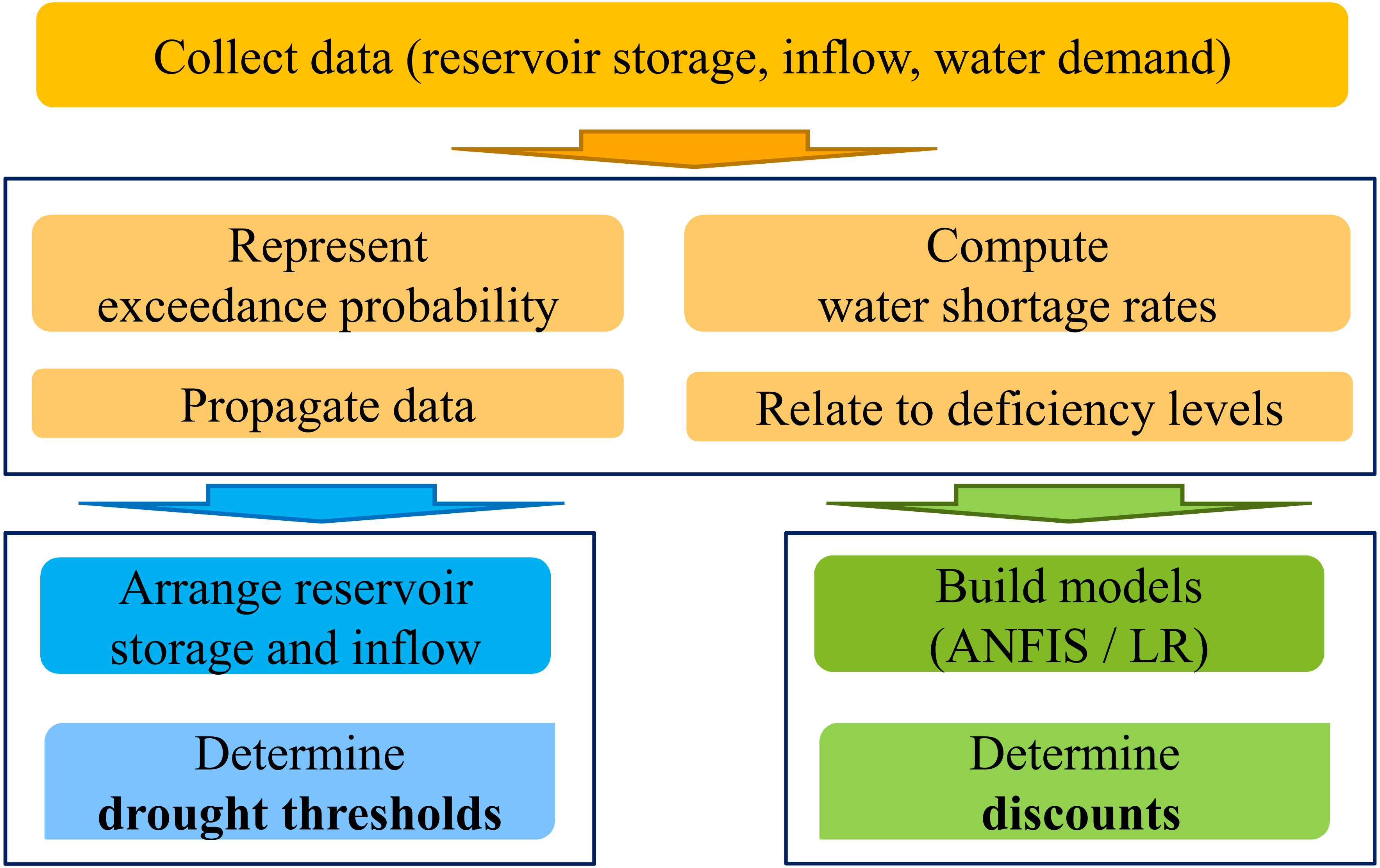
Water Resources & Hydroinformatics System Lab

Historic fallow decisions

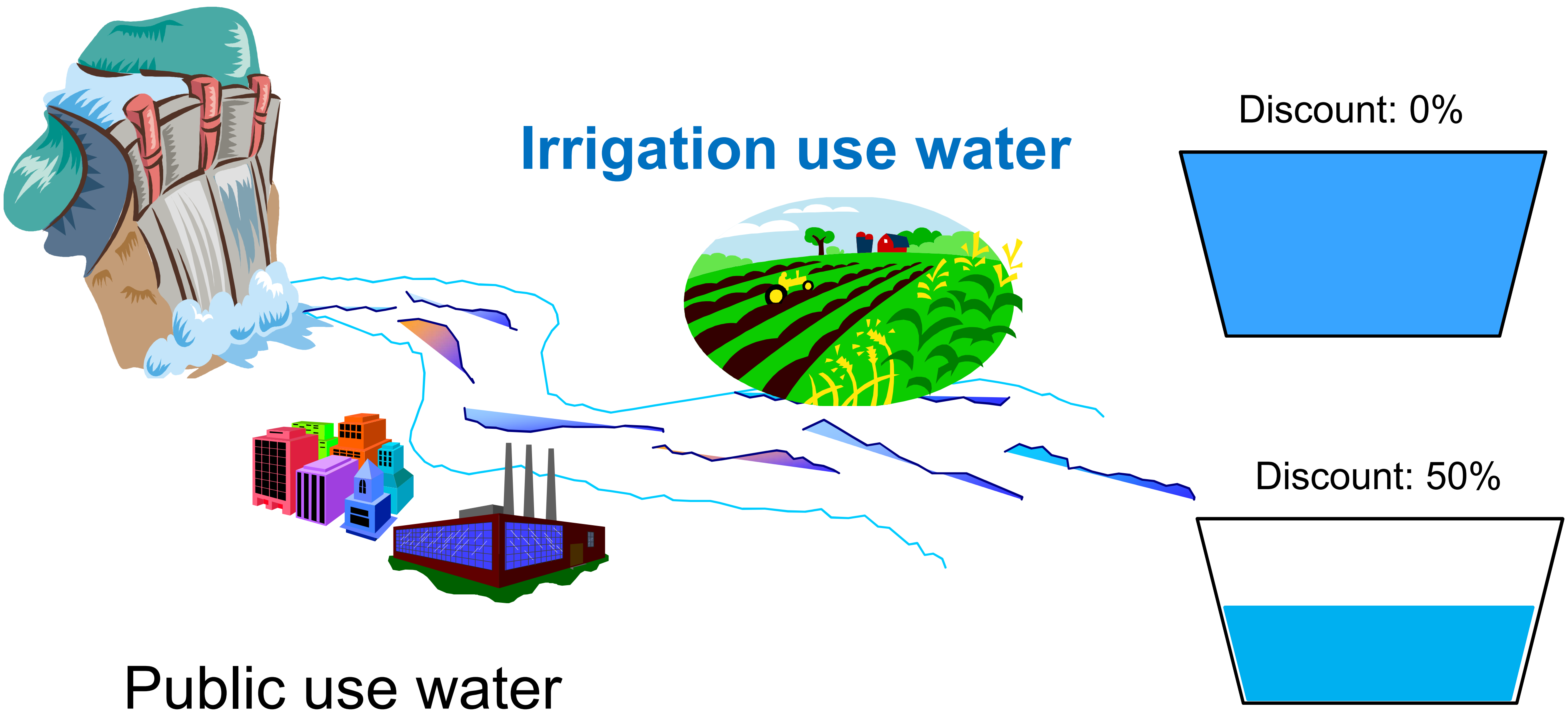
Year	Announcement date	Discount on irrigation use water from the fallow area
1973	–	10%
1977	–	40%
1991	–	50%
1994	–	100%
1996	–	100%
2002	3/1 5/3	70% 100%
2003	1/30	70%
2004	1/7	100%

extensive farmland lain fallow！

Intelligent water allocation strategy



Discounts

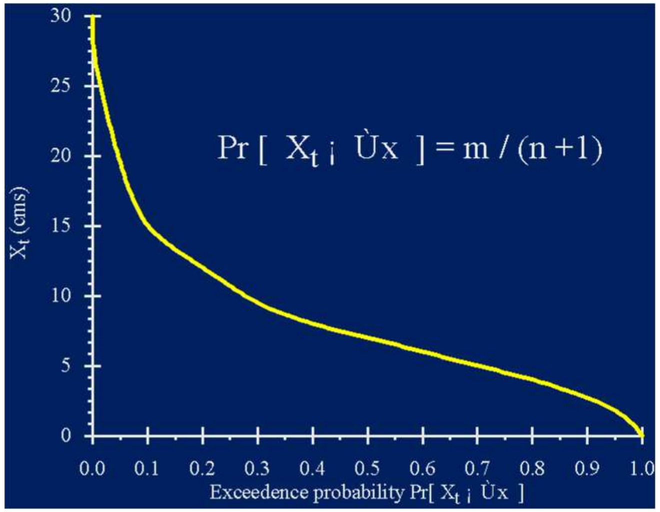

Irrigation use water
Discount: 0%
Discount: 50%
Public use water

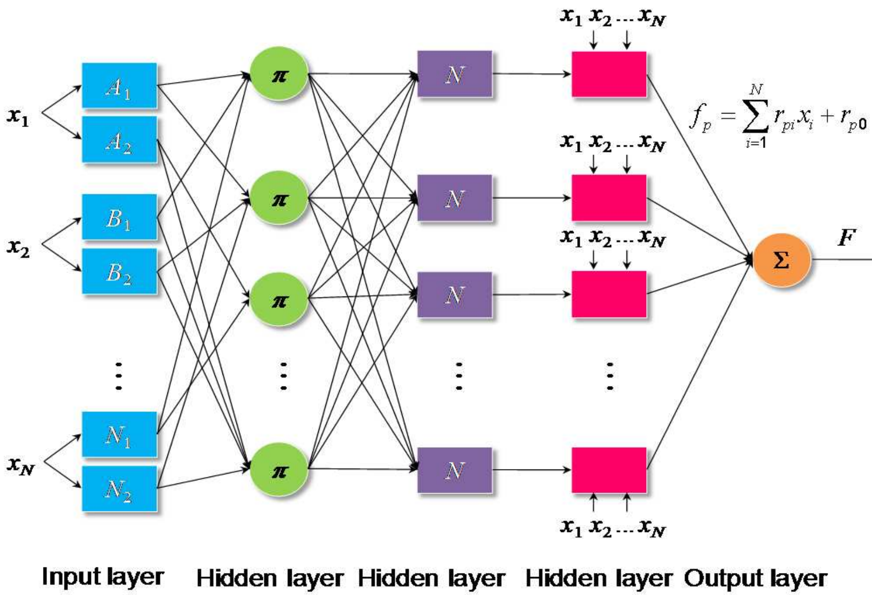
Methodology

Background

◆**The Exceedence Probability** is used for data preprocessing.

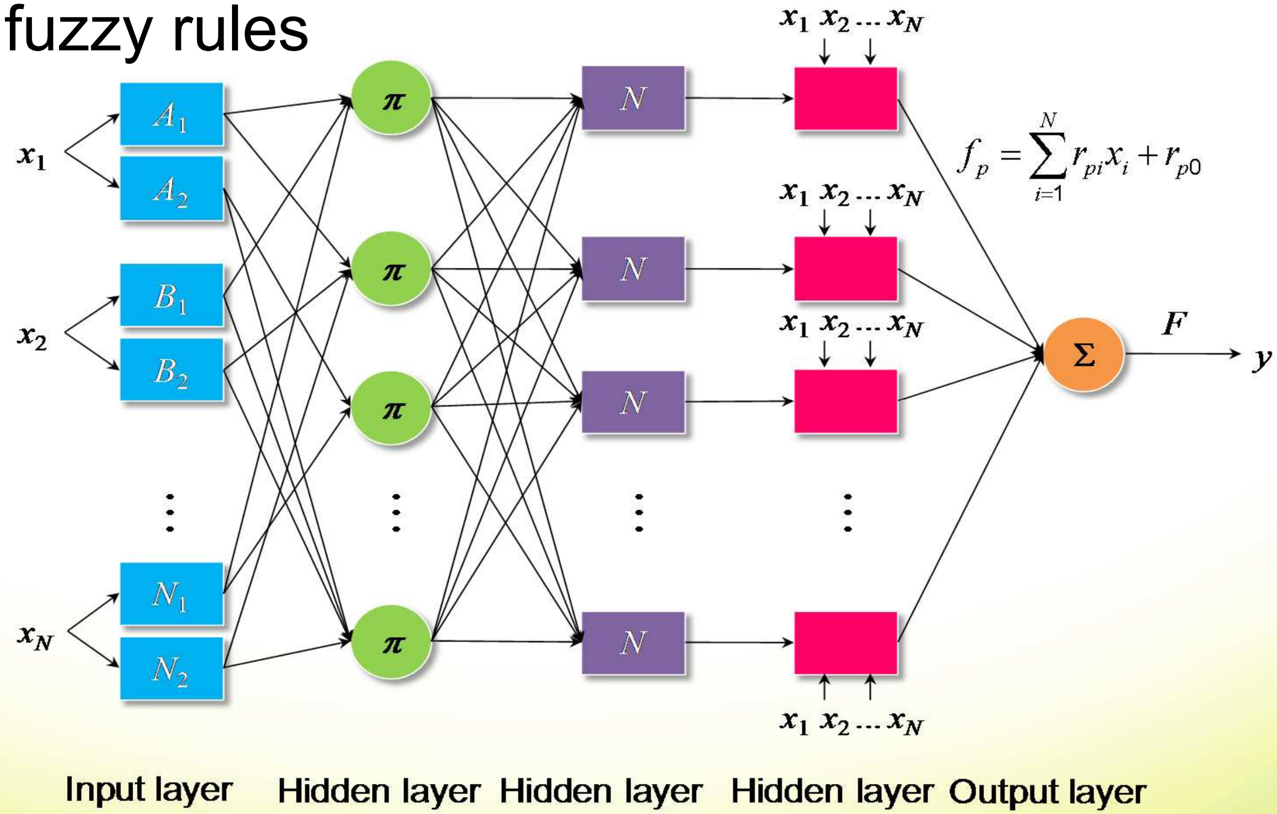
◆**ANFIS** is used to estimate drought situations.





Adaptive neuro-fuzzy inference system (ANFIS)

- multilayer feed-forward network
- supervised learning scheme
- fuzzy rules

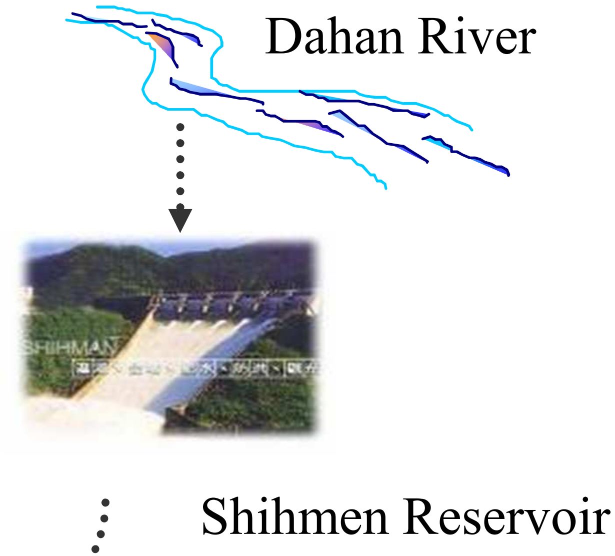


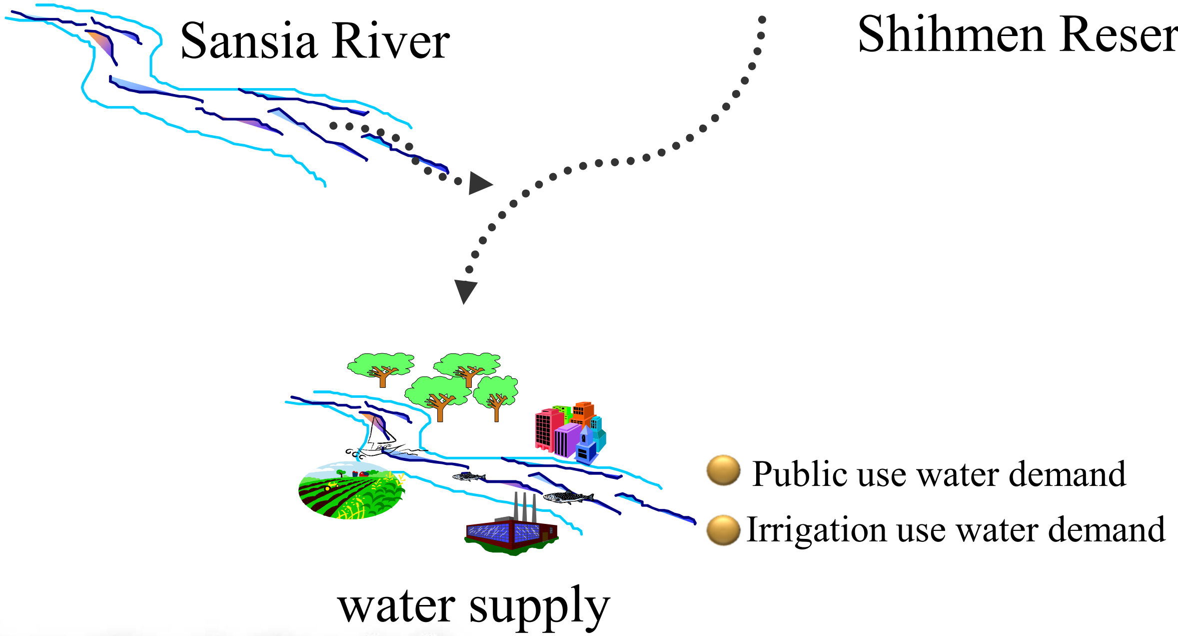
Case study

Case study

Shihmen Reservoir
in northern Taiwan

- Data length: 44 years (1965-2008)
- Adjust water resources for the years 1973, 1977, 1984, 1991, 1994, 1996, **2002**, 2003 and **2004**
- 10-day simulation





Objective function

$$SR = \frac{1}{T - t_0}\left[\sum_{t=t_0}^{T} max\left(\frac{D(t) - R(t)}{D(t)}, 0\right)\right]$$

average 10-day **water shortage rate**

- $Q_{S2b}(t) = max\left[D_{ban}(t) - Q_{san}(t), 0\right]$ water release from the Sansia River to the Banshin District
- $S(t) = S(t-1) + Q_{in}(t) - E(t) + min\left[0, Q_b(t) - D_{Pub}(t) - D_{Irr}(t) - Q_{S2b}(t) - B(t)\right]$ water balance
- $Q_{san}(t) \le 5.3 \times 10^5 (m^3 / day)$ upper bound of inflow for the Sansia River
- $S_{\min} \le S(t) \le S_{\max}$ boundary of storage
- $Q_{in}, Q_{san}, D_{irr}, D_{pub}, D_{ban}, E, B \ge 0$ positive conditions

T	*termination time*
t_0	*initial time for each case*
D	*downstream water demand*
R	*release water*
S	*reservoir storage*
Q	*reservoir & river inflow*
E	*evaporation*
B	*ecological base flow*

Judgment of water deficiency levels corresponding to water shortage rates

Deficiency level	Water shortage rate (%)	
	Irrigation use	Public use
1 (normal)	0	0
2 (slightly high)	0 - 30	0 - 10
3 (high)	30 - 40	10 - 20
4 (very high)	40 - 50	20 - 30
5 (extremely high)	> 50	> 30

Issue 1 drought thresholds

Issue 2 appropriate discounts

Case I early warning

Case II suspend fallow strategy

January | February ------------------------------> April

1st	2nd	3rd	4th	5th	6th	7th	8th	9th	10th	11th	12th

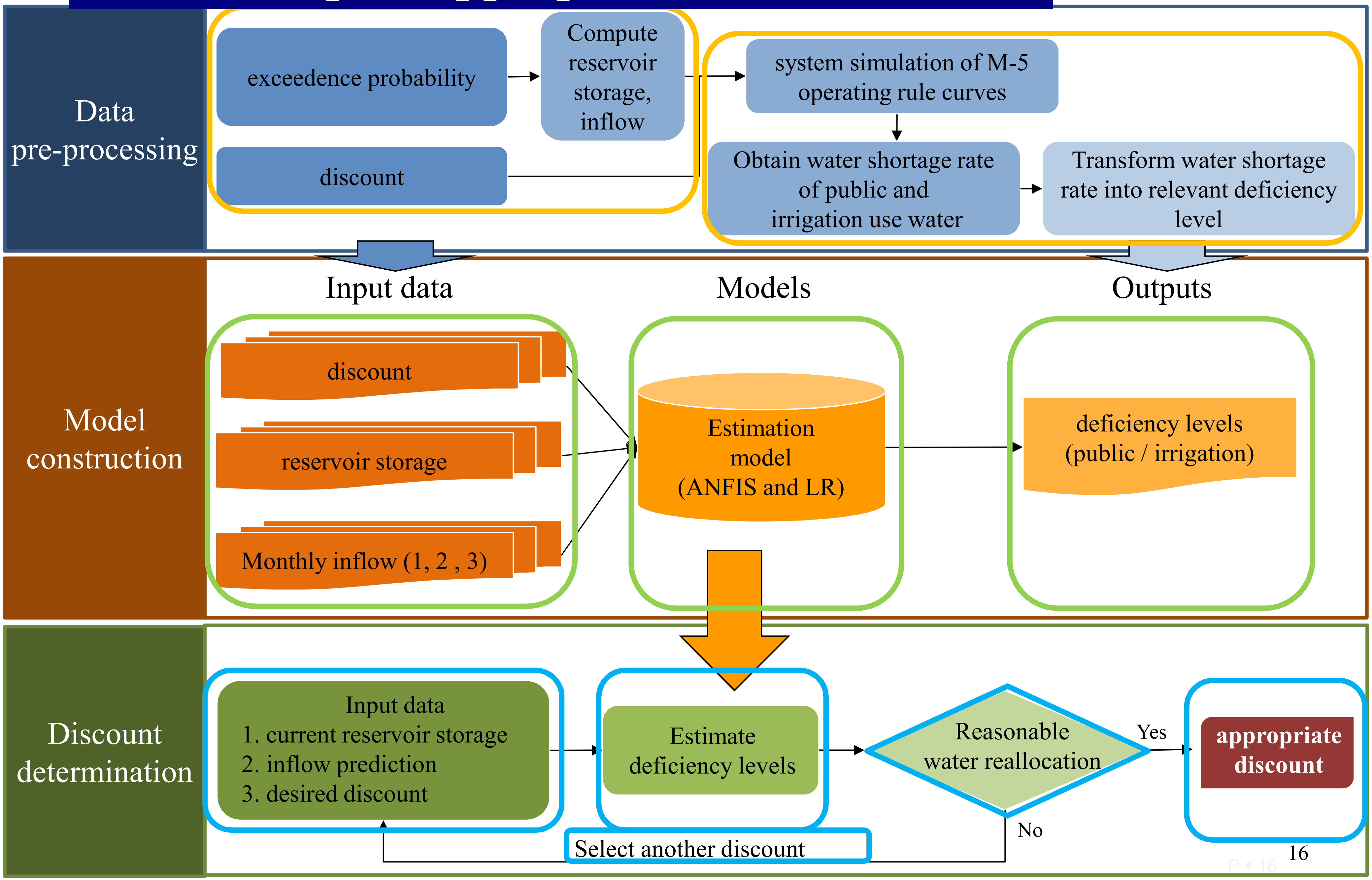
Case I (publicize an early warning 1 month before the growth period of the first crop of paddy)

Issues 1 and 2 (1st – 9th)

Case II (publicize a late fallow strategy at the beginning of the growth period of the first crop of paddy)

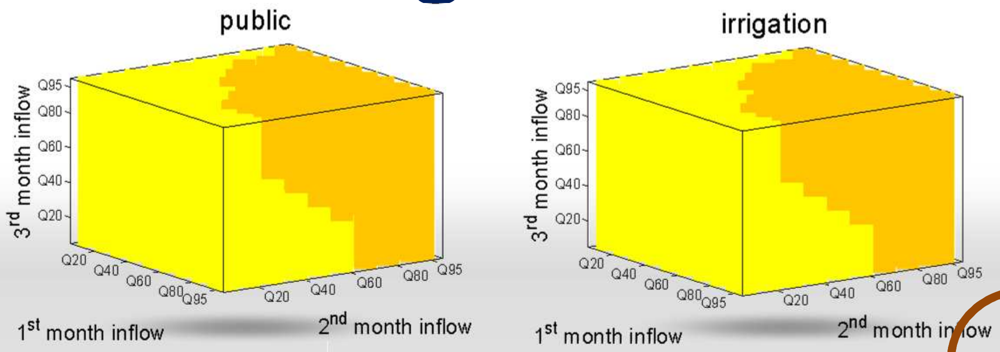
Issues 1 and 2 (4th – 12th)

Propose appropriate discount

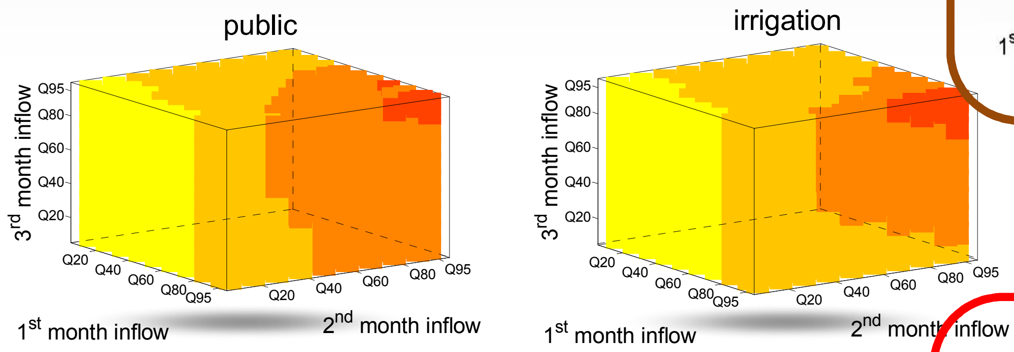


Results

Drought thresholds - reservoir storage (Case I)

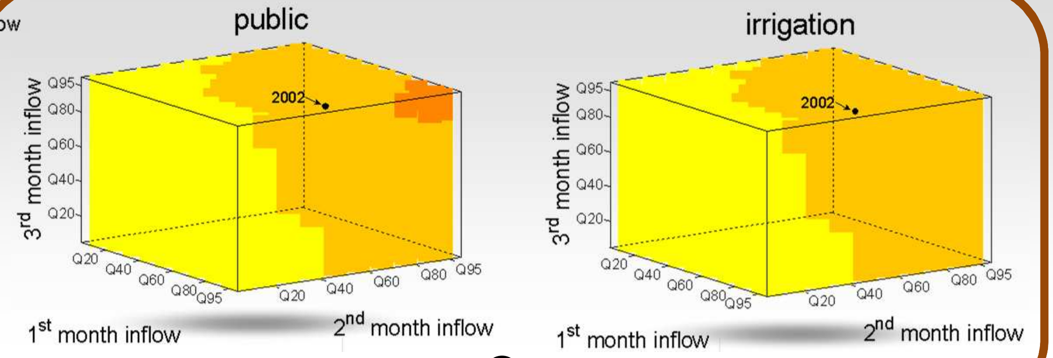


Q_{60}



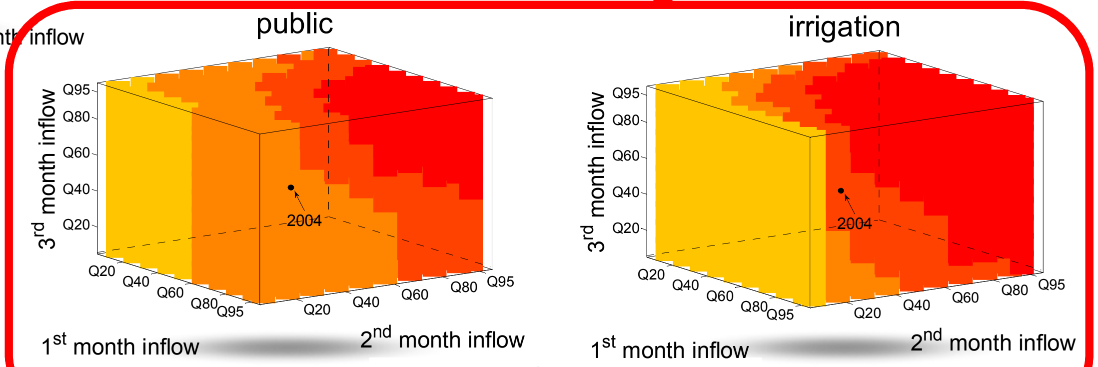
Q_{80}

slight drought



Q_{70}

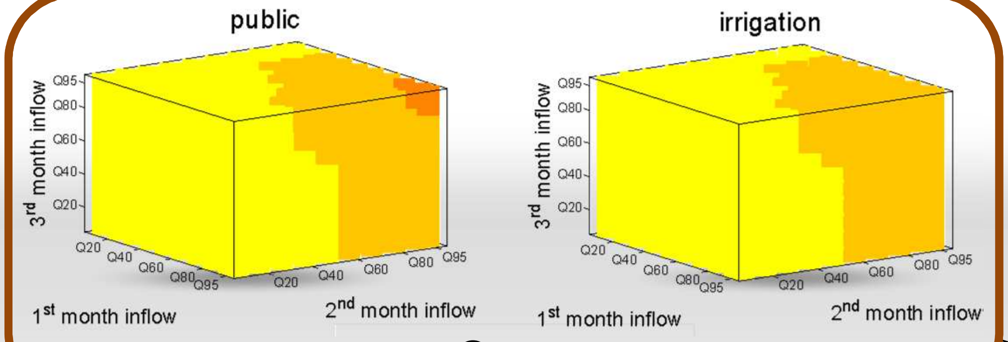
severe drought



Q_{90}

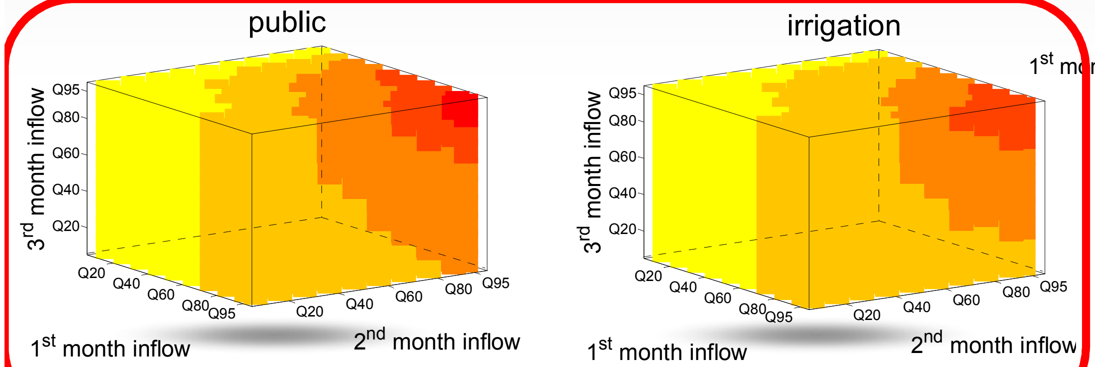
Drought thresholds - reservoir storage (Case II)

slight drought

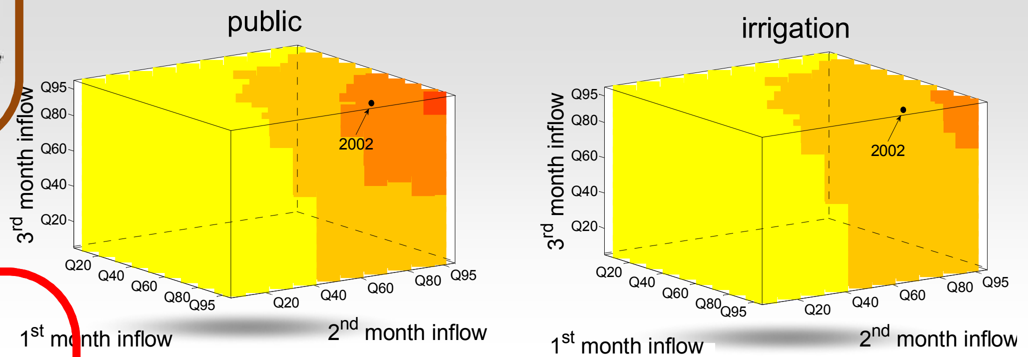


Q_{60}

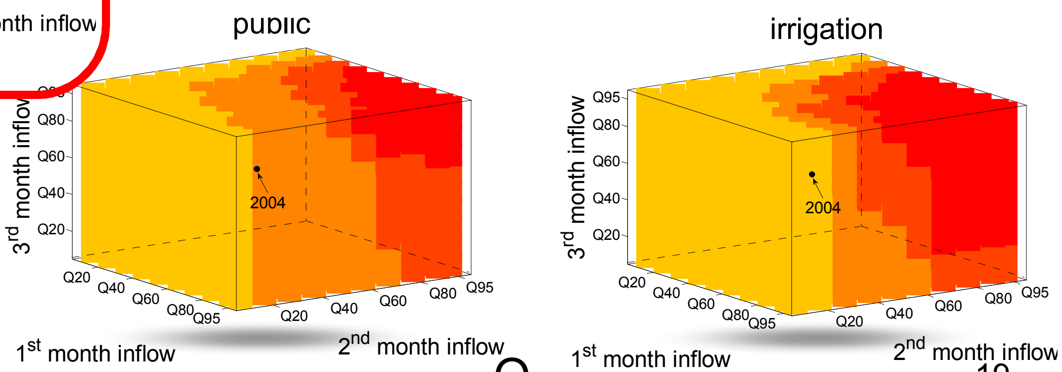
severe drought



Q_{80}



Q_{70}



Q_{90}

Drought thresholds
- inflow

Qp indicates the inflow data associated with Exceedence probability.

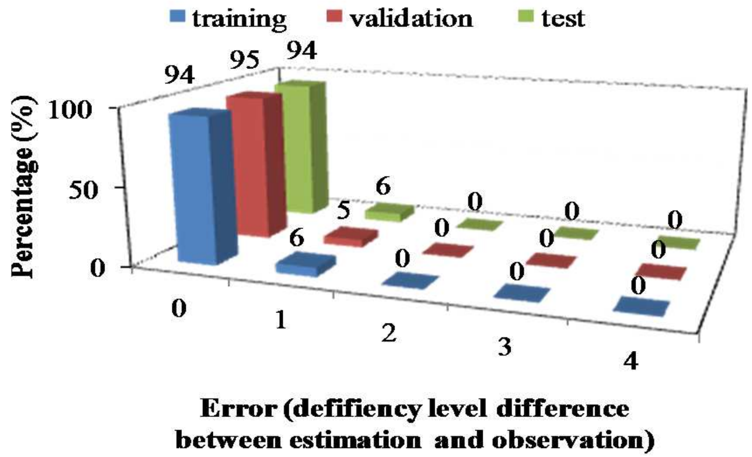
Year corresponding to Inflow

exceedence probability (Qp)	Month 1st	2nd	3rd	1st - 3rd
2	1972	[illegible]	[illegible]	1983
4	2001	[illegible]	[illegible]	1998
7	1986	[illegible]	1992	1992
9	1990	1998	2005	1985
11	1975	1968	1985	2005
13	1973	2000	1986	1968
16	1970	2005	1968	1986
18	1999	2001	2000	2000
20	1976	1972	1978	2001
22	1978	1986	1970	1978
24	2005	1980	1975	1972
27	1971	1990	1990	1990
29	1983	1975	2001	1975
31	1998	1995	1995	1970
33	2007	1994	1980	1980
36	1992	1971	1972	1995
38	1988	1978	1994	1994
40	1968	1970	1982	1971
42	1965	1973	1997	1982
44	1980	1997	1971	1997
47	1993	1977	1987	1999
49	2000	2004	1993	1988
51	1979	1976	1988	1973
53	1982	2008	2004	1976
56	1977	1999	2006	2004
58	1967	1988	1999	1993
60	2008	1991	2007	2007
62	2006	1967	1969	1977
64	1989	2007	1979	2006
67	2002	1982	1976	2008
69	1995	1979	2008	1987
71	1991	1993	1967	1979
73	2003	2006	1973	1967
76	1987	2002	1981	1991
78	1985	1965	1977	1965
80	1994	1989	1991	1969
82	2004	1974	1974	1974
84	1974	1987	1966	1981
87	1997	2003	1965	2002
89	1984	1969	1989	1989
91	1981	1966	2002	1966
93	1966	1981	1984	2003
96	1969	1984	2003	1984
98	1996	1996	1996	1996

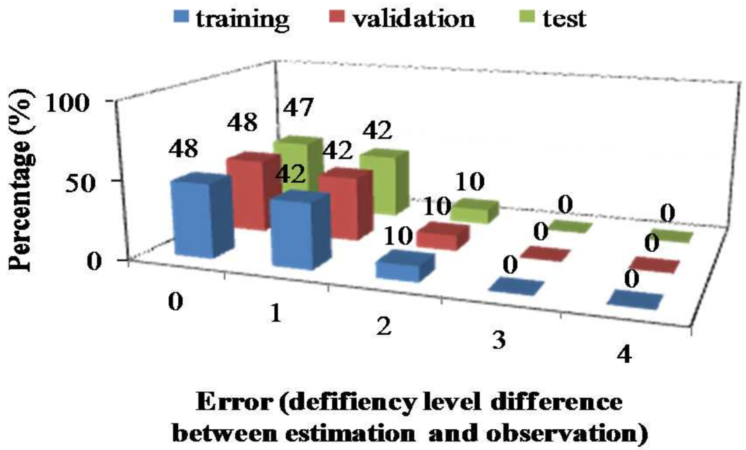
slight drought Q_{50}

severe drought Q_{70}

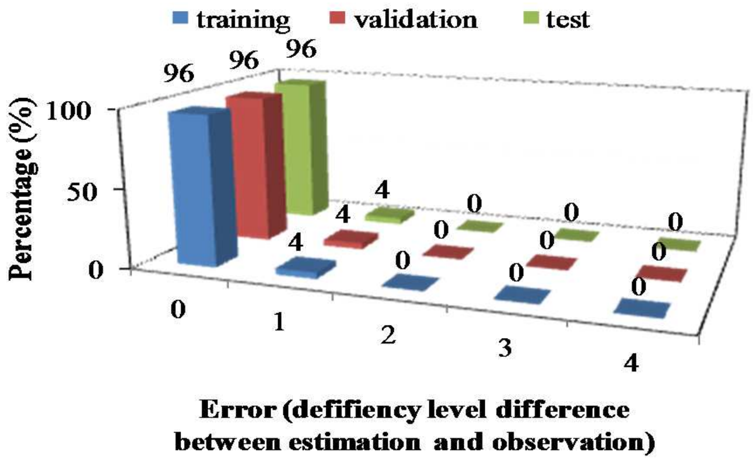
Performance of ANFIS and linear regression for deficiency level estimation (Case I)



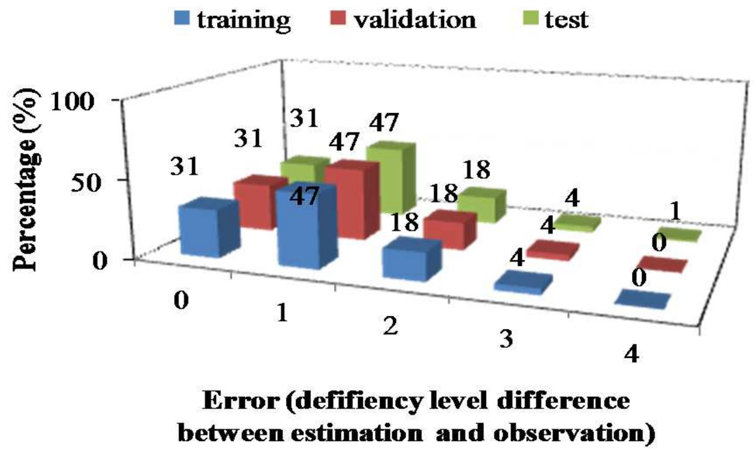
public use water (ANFIS)



public use water (LR)



irrigation use water (ANFIS)



irrigation use water (LR)

Appropriate discount

	year 2002				year 2004			
	Case I		Case II		Case I		Case II	
discount	public	irrigation	public	irrigation	public	irrigation	public	irrigation
0%	2	2	3	3	3	4	3	3
10%	2	2	3	3	3	4	3	3
20%	2	2	3	3	3	4	3	3
30%	2	3	2	3	3	4	3	3
40%	2	4	2	4	3	4	2	4
50%	2	4	2	5	3	4	2	4
60%	1	5	1	5	3	5	2	5
70%	1	5	1	5	3	5	2	5
80%	1	5	1	5	3	5	2	5
90%	1	5	1	5	3	5	2	5
100%	1	5	1	5	3	5	2	5

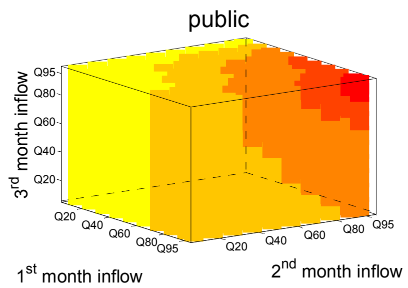
all farmlands lain fallow in these two years (2002 and 2004)

Conclusions

Conclusion

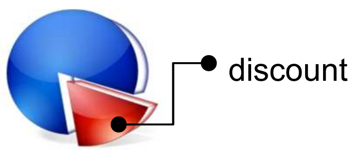
Drought threshold

- Show a whole perspective of drought conditions by **threshold figures**
- Initial reservoir **storage** - **Slight drought: $Q_{70} – Q_{60}$**
  Severe drought $Q_{90} – Q_{80}$
- **Inflow** - **Slight drought: Q_{50}**
  Severe drought Q_{70}



Discount

- Establish a discount determination process for irrigation use water
- Need **reasonable upcoming three-month inflow**
- Avoid the occurrence of **large-scale fallow areas**



Thanks for your attention!!