

*Hydro Predict'2012*



Graduate Institute of Bioenvironmental Systems Engineering National  
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## **Intelligent water allocation strategy: a case study in northern Taiwan**

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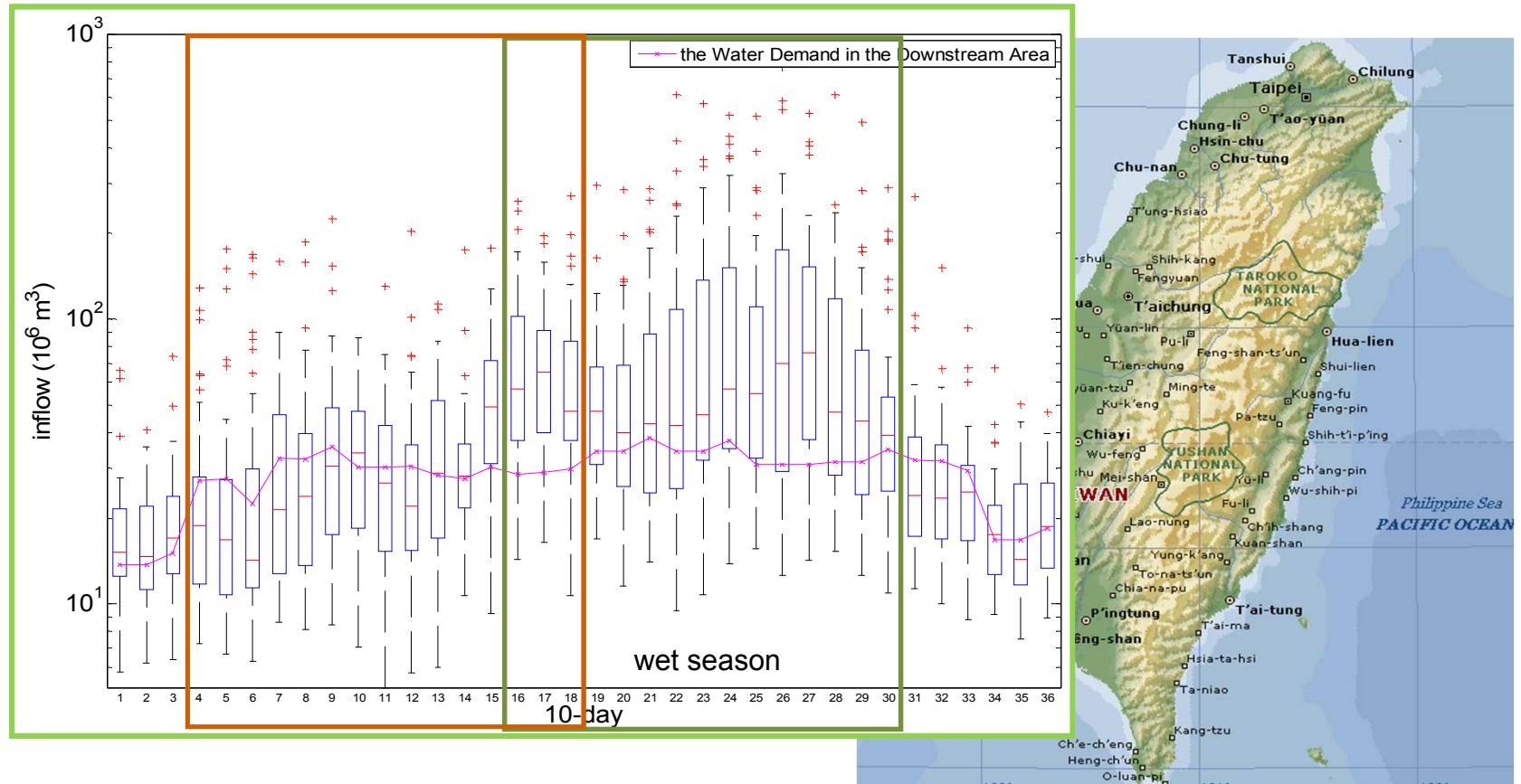




# Background

# Background

- non-uniform distribution of water resources



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

*Water Resources & Hydroinformatics System Lab*

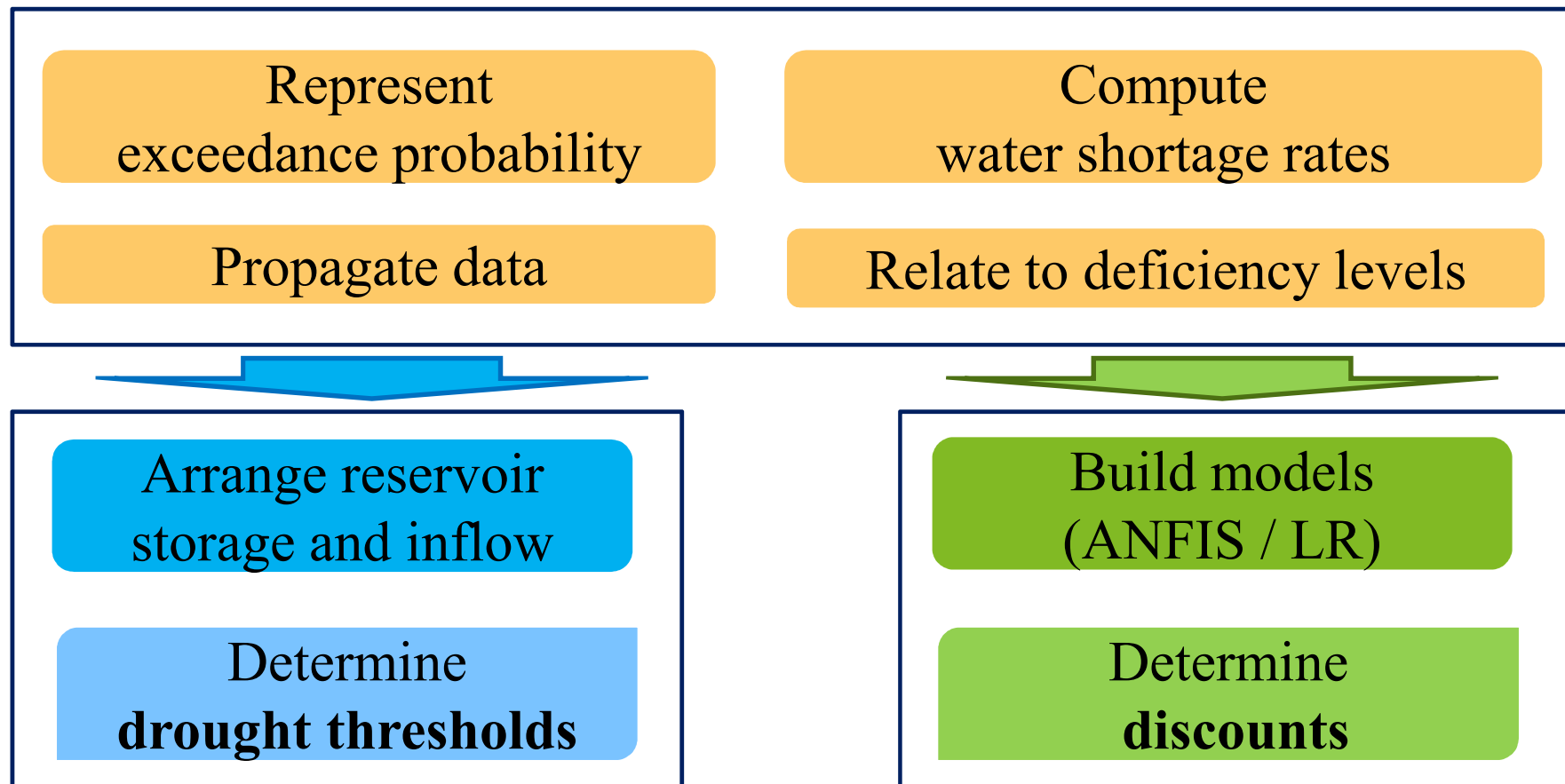
# Historic fallow decisions

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	70%
	5/3	100%
2003	1/30	70%
2004	1/7	100%

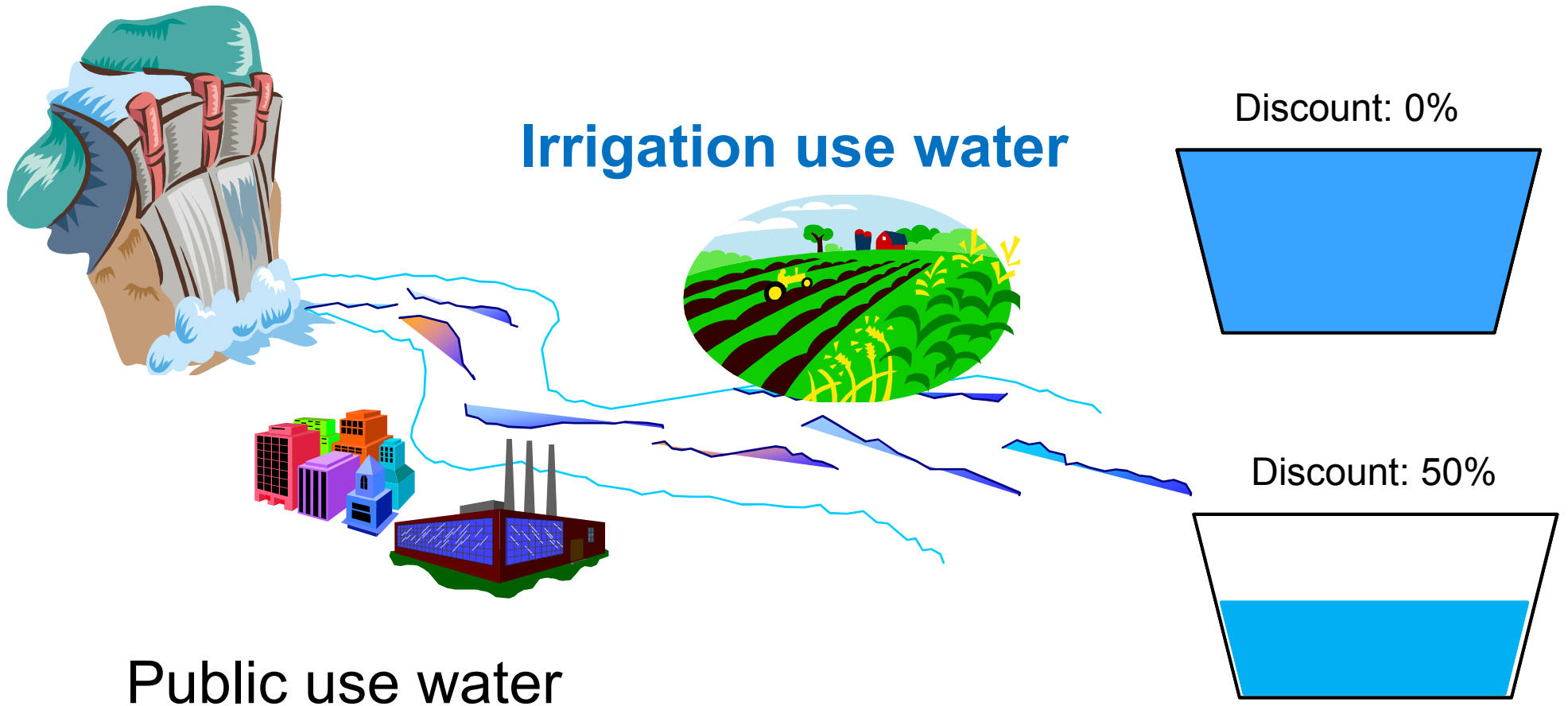
extensive farmland lain fallow !

# Intelligent water allocation strategy

Collect data (reservoir storage, inflow, water demand)



# Discounts



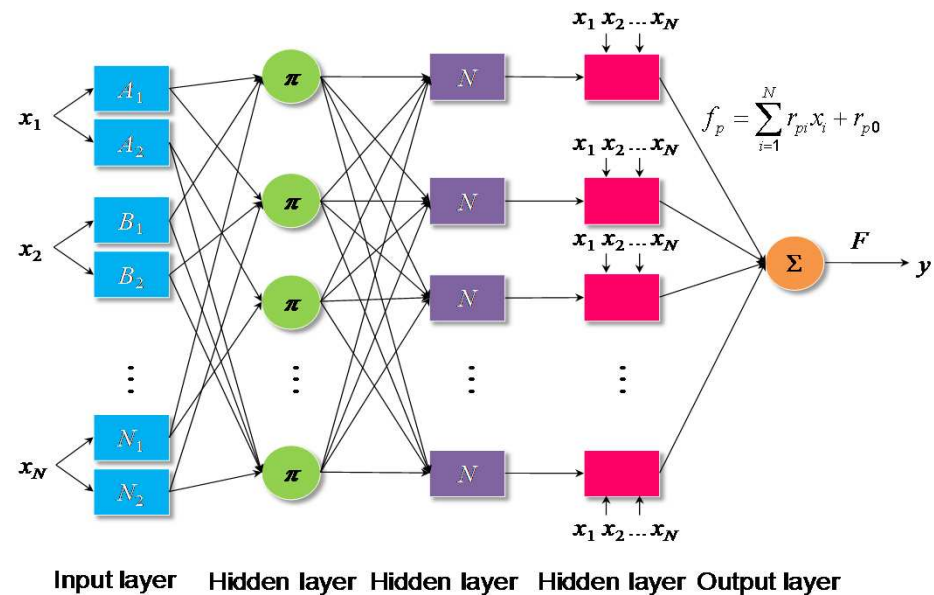
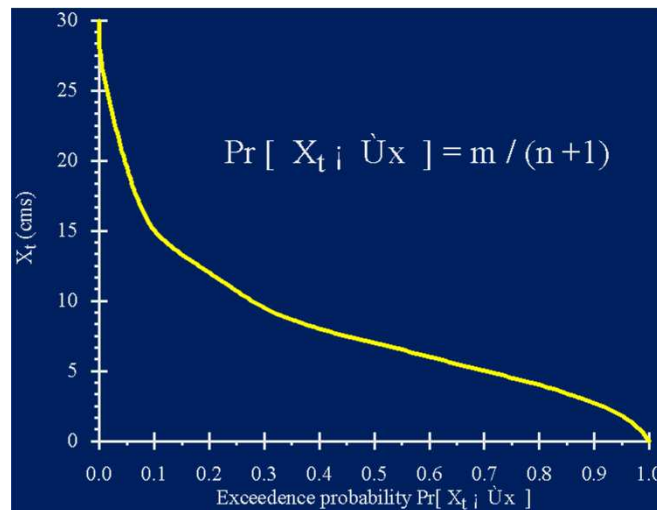
The background of the slide features a vibrant blue gradient at the top, transitioning into a dynamic splash of liquid. The splash consists of a large, flowing wave on the left and two smaller, spherical droplets on the right, all set against a white background. The liquid has a glossy, reflective surface with highlights and shadows, giving it a three-dimensional appearance.

# Methodology



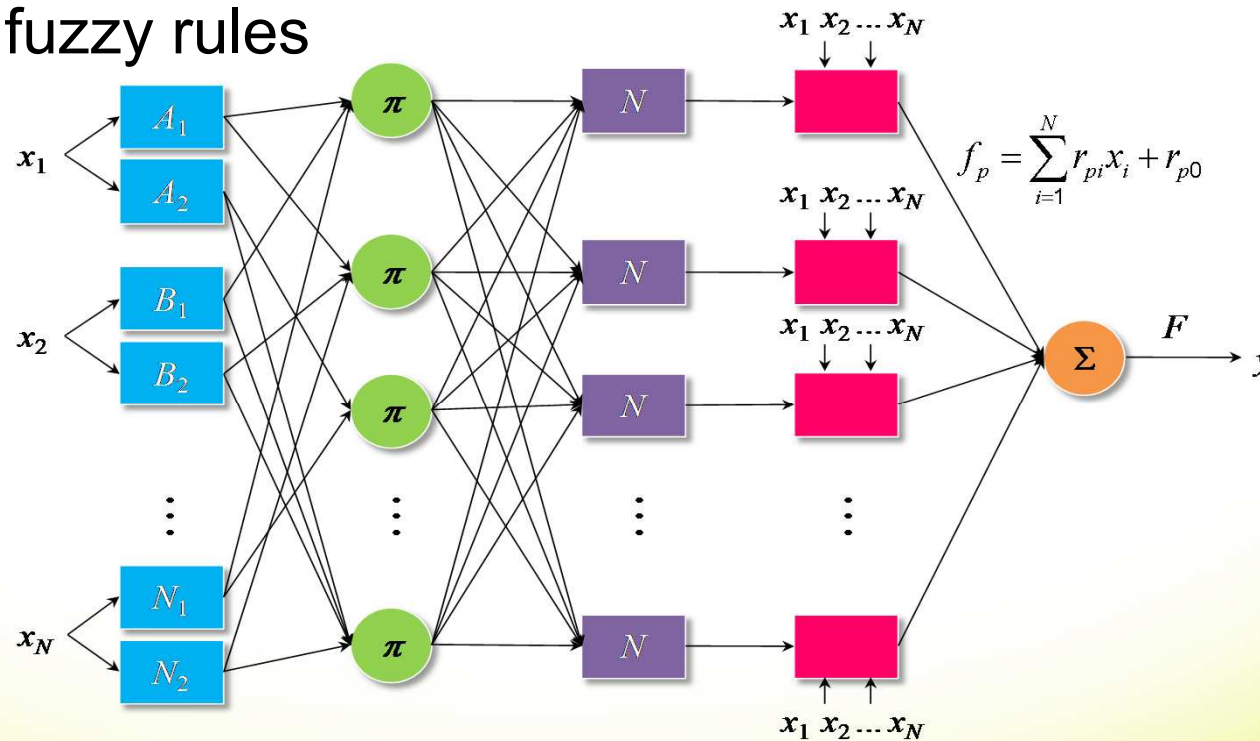
# Background

- ◆ 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



Input layer    Hidden layer    Hidden layer    Hidden layer    Output layer

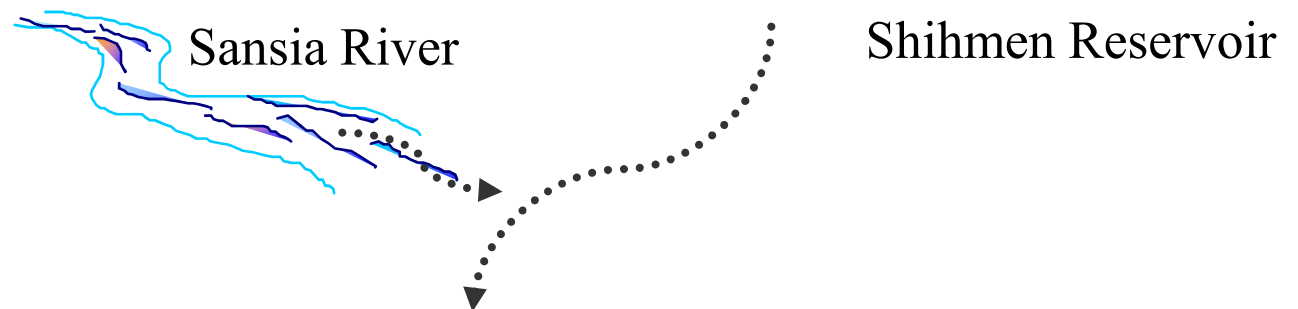
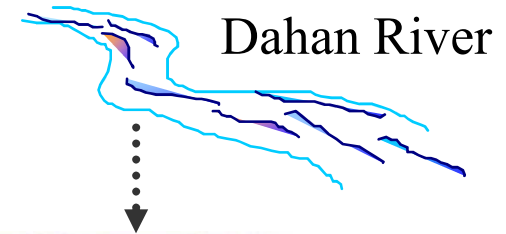
The background of the slide features a vibrant blue gradient at the top, transitioning into a white surface where a dynamic splash of blue liquid flows from the left. Several clear, spherical bubbles of varying sizes are scattered on the white surface, reflecting light and adding a sense of movement and freshness to the design.

# 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



- Public use water demand
- Irrigation use water demand

water supply

*informatics System Lab*

# Objective function

$$SR = \frac{1}{T - t_0} \left[ \sum_{t=t_0}^T \max \left( \frac{D(t) - R(t)}{D(t)}, 0 \right) \right] \quad \text{average 10-day water shortage rate}$$

$$Q_{S2b}(t) = \max [D_{ban}(t) - Q_{san}(t), 0] \quad \text{water release from the Sansia River to the Banshin District}$$

$$S(t) = S(t-1) + Q_{in}(t) - E(t) + \min [0, Q_b(t) - D_{pub}(t) - D_{irr}(t) - Q_{S2b}(t) - B(t)] \quad \text{water balance}$$

$$Q_{san}(t) \leq 5.3 \times 10^5 (m^3 / day) \quad \text{upper bound of inflow for the Sansia River}$$

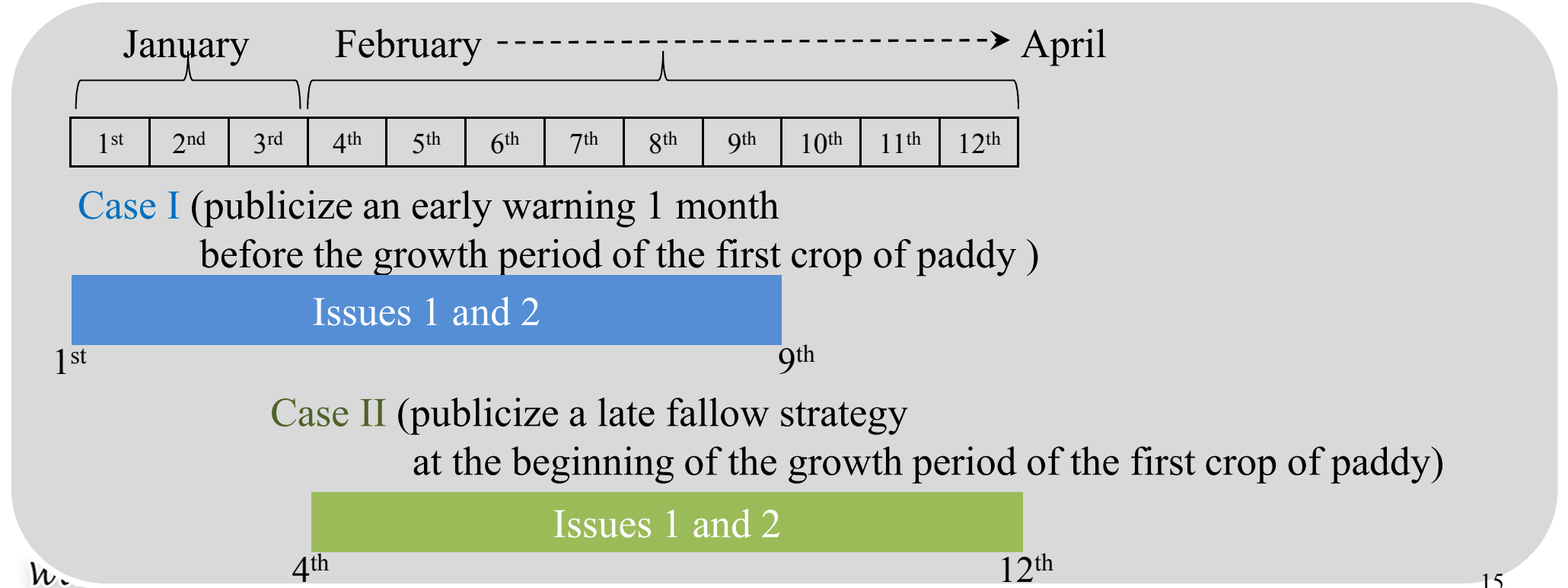
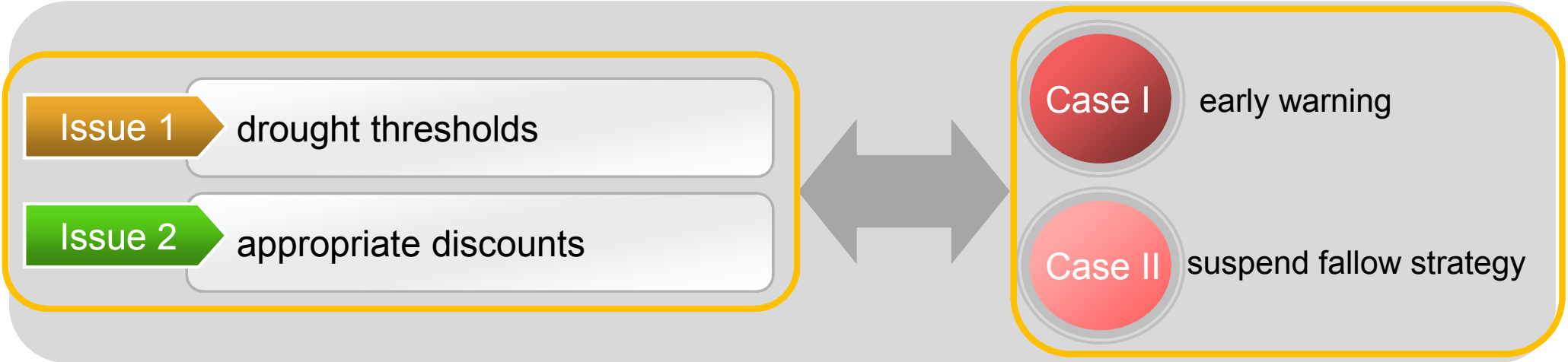
$$S_{min} \leq S(t) \leq S_{max} \quad \text{boundary of storage}$$

$$Q_{in}, Q_{san}, D_{irr}, D_{pub}, D_{ban}, E, B \geq 0 \quad \text{positive conditions}$$

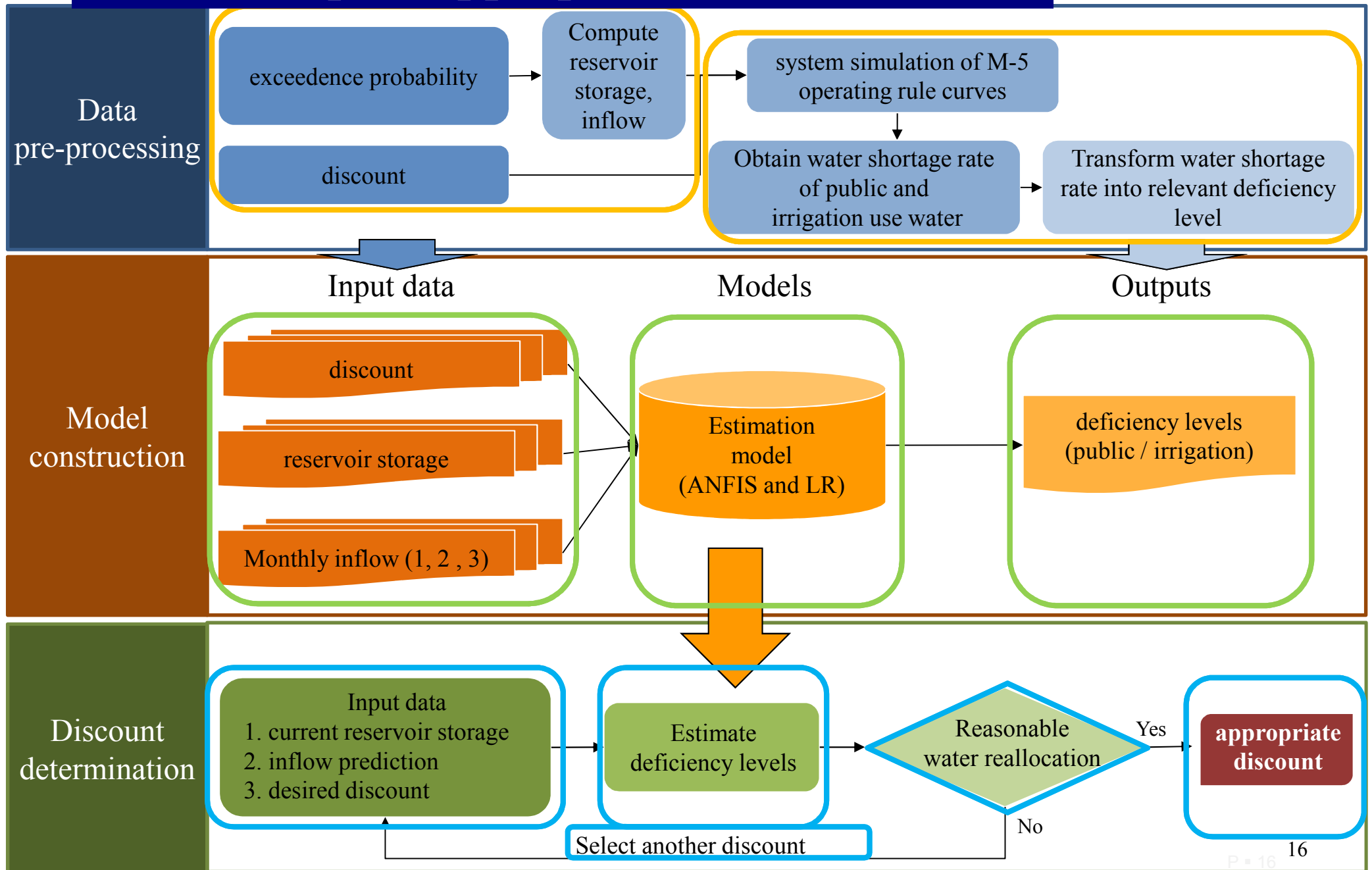
$T$	<i>termination time</i>
$t_0$	<i>initial time for each case</i>
$D$	<i>downstream water demand</i>
$R$	<i>release water</i>
$S$	<i>reservoir storage</i>
$Q$	<i>reservoir &amp; river inflow</i>
$E$	<i>evaporation</i>
$B$	<i>ecological base flow</i>

# 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



# Propose appropriate discount

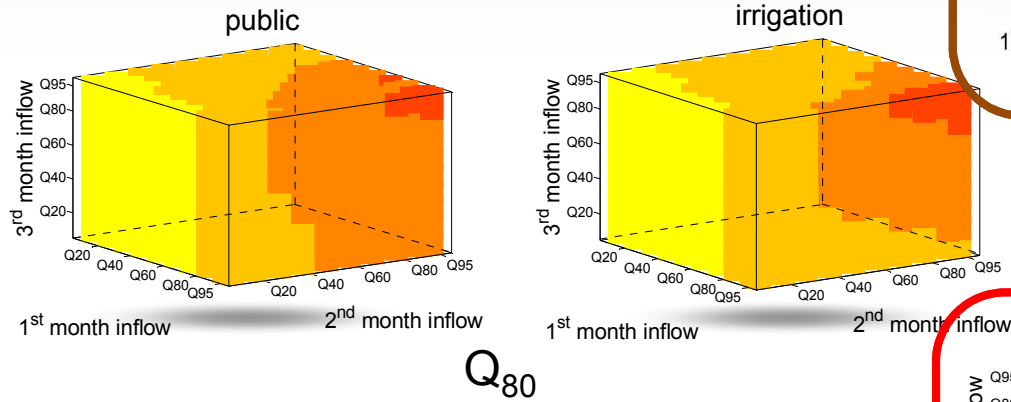
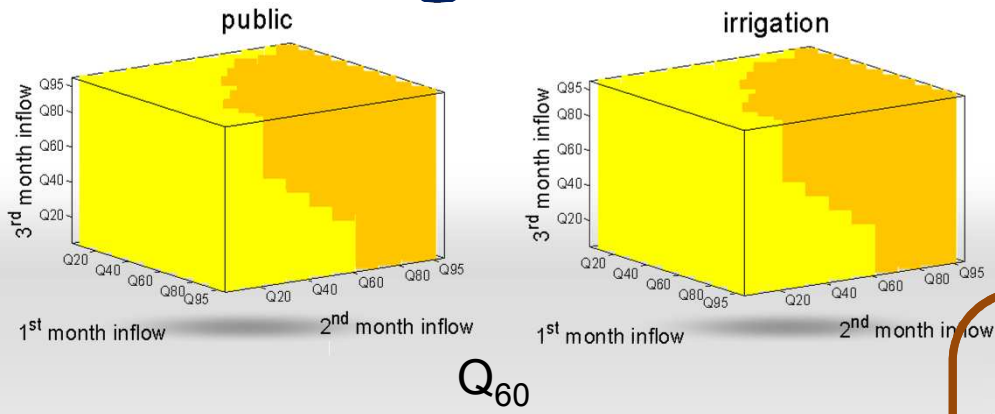




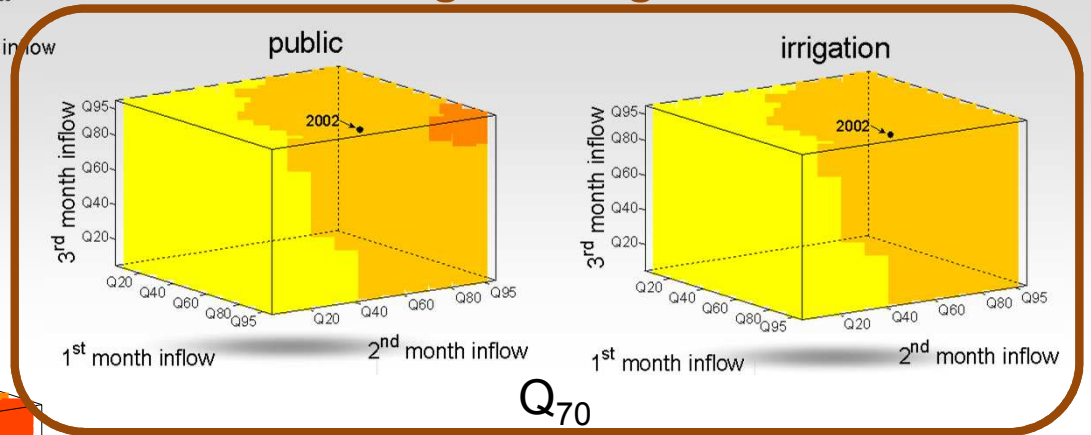
A background image featuring a vibrant blue gradient. In the lower half, there is a dynamic splash of blue liquid that flows from the left towards the right, creating a series of rounded, overlapping shapes. Below the main splash, two distinct, spherical droplets of varying sizes are positioned on the right side, each with a bright highlight on its upper surface, giving them a three-dimensional appearance.

# Results

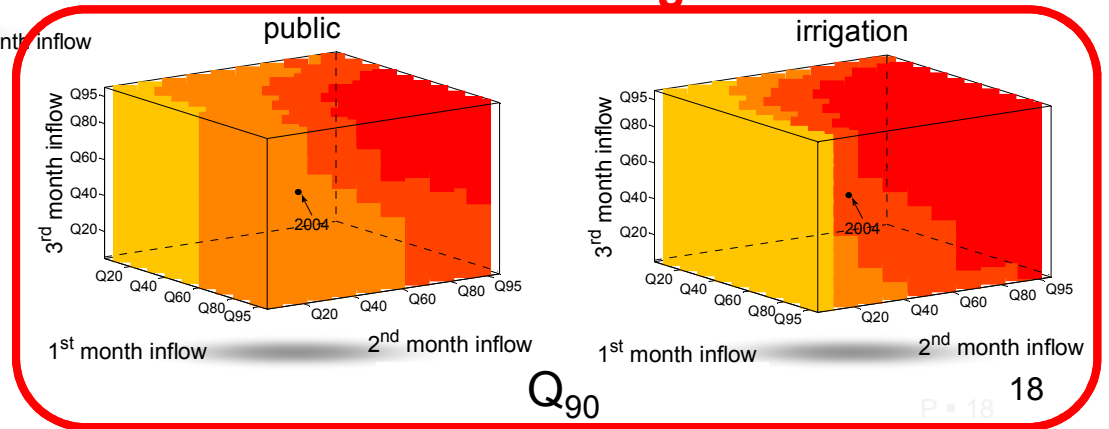
# Drought thresholds - reservoir storage (Case I)



slight drought

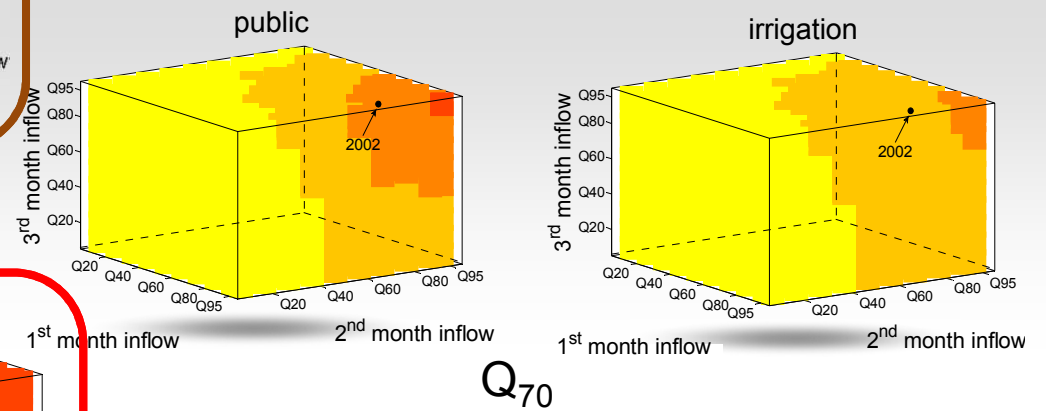
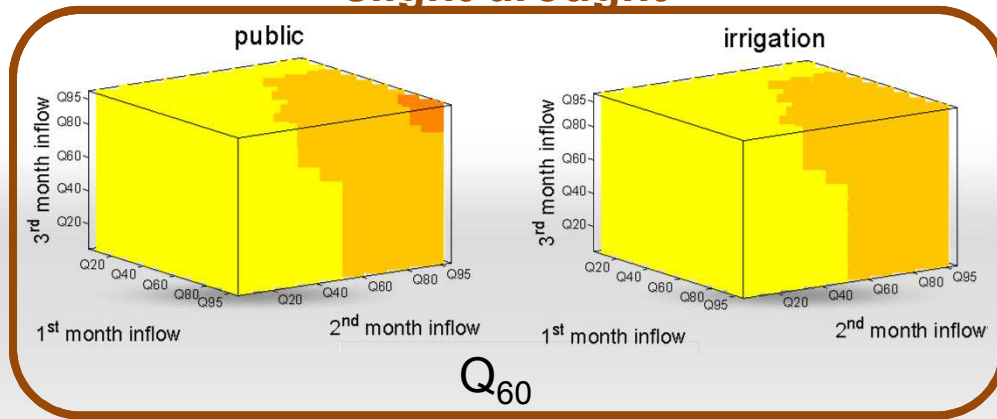


severe drought

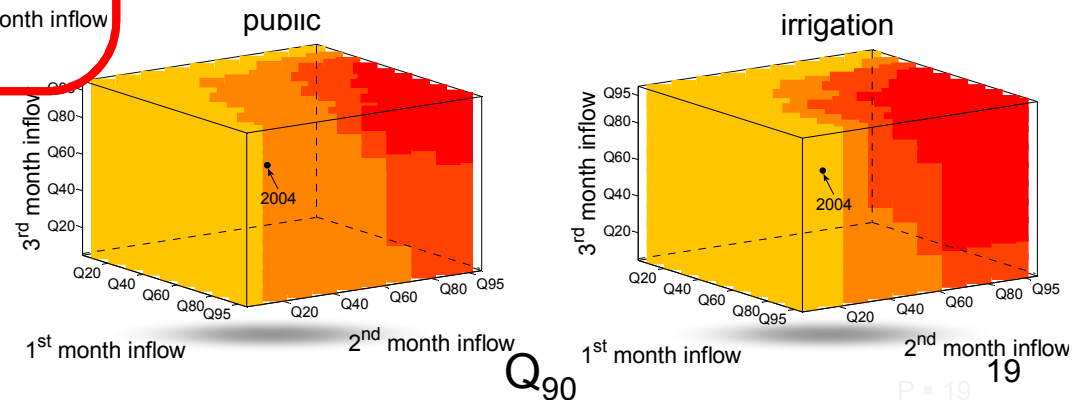
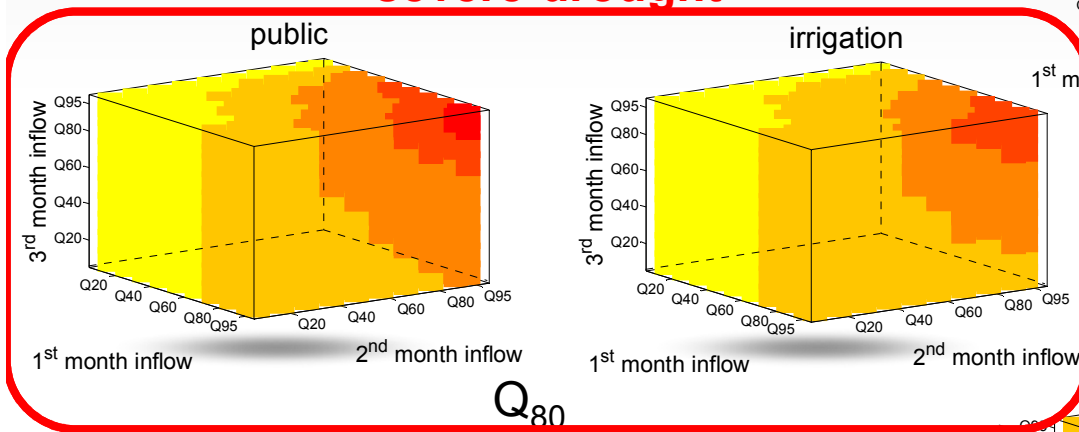


# Drought thresholds - reservoir storage (Case II)

## slight drought



## severe drought



# Drought thresholds - inflow

Qp indicates the inflow data associated with Exceedence probability.

slight drought

severe drought

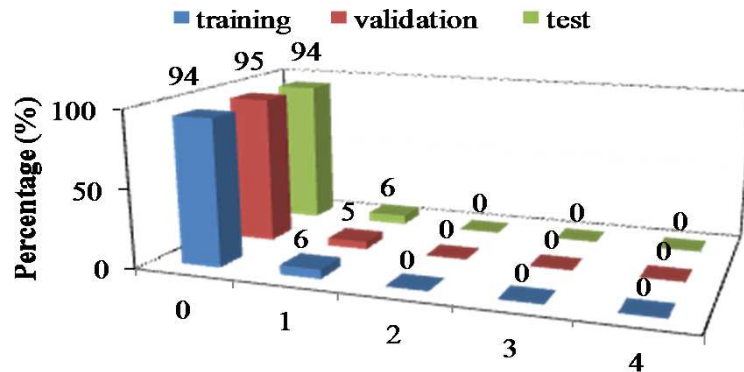
exceedence probability (Qp)	Month				
	1st	2nd	3rd	1st - 3rd	
2	1972				1983
4	2001				1998
7	1986				1992
9	1990		1998	2005	1985
11	1975		1968	1985	2005
13	1973		2000	1986	1968
16	1970		2005	1968	1986
18	1999		2001	2000	2000
20	1976		1972	1978	2001
22	1978		1986	1970	1978
24	2005		1980	1975	1972
27	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

Year corresponding to Inflow

Q<sub>50</sub>

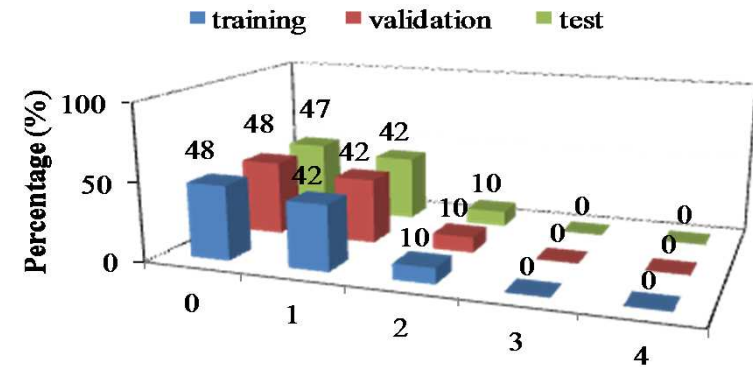
Q<sub>70</sub>

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



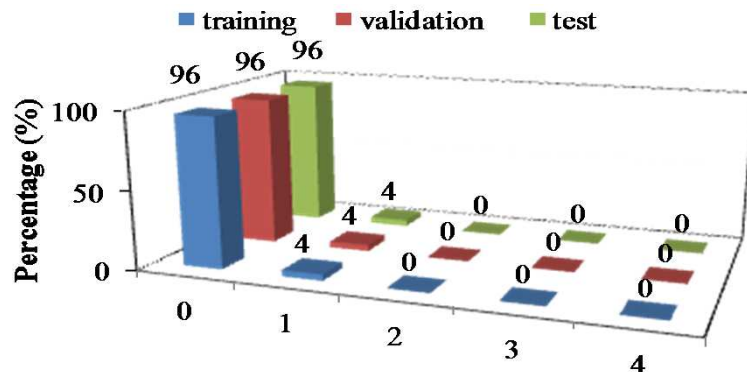
Error (deficiency level difference between estimation and observation)

public use water (ANFIS)



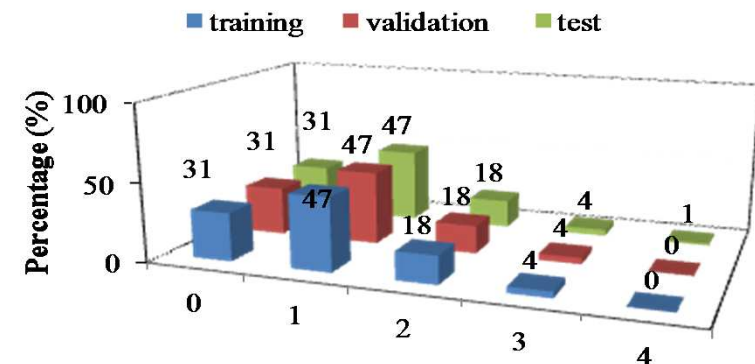
Error (deficiency level difference between estimation and observation)

public use water (LR)



Error (deficiency level difference between estimation and observation)

irrigation use water (ANFIS)



Error (deficiency level difference between estimation and observation)

irrigation use water (LR)

# Appropriate discount

discount	year 2002				year 2004			
	Case I		Case II		Case I		Case II	
	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)

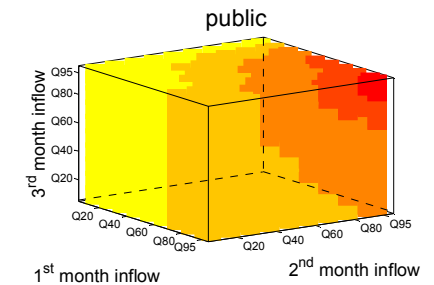
The background of the slide features a vibrant blue liquid splash that flows from the top left towards the bottom right. The splash is rendered with a glossy, 3D effect, showing highlights and shadows that give it a sense of depth and movement. The liquid appears to be splashing onto a white surface, creating a clean, bright contrast. The overall aesthetic is modern and clean, typical of a professional presentation.

# Conclusions

# Conclusion

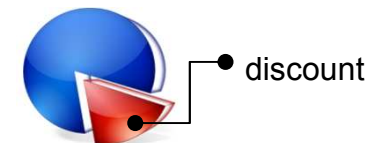
## Drought threshold

- 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**





The background of the slide features a vertical blue gradient, transitioning from a darker blue on the left to a lighter, almost white blue on the right. Scattered throughout this gradient are numerous small, semi-transparent bubbles of varying sizes, some appearing to rise from the bottom. The text is centered in a white, bold, sans-serif font.

**Thanks for your attention!!**