XVIII World Water Congress
International Water Resources Association (IWRA)

Research framework for hierarchy of water needs adapting to extreme drought management

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XVIII WORLD WATER CONGRESS
Water for All
Harmony between Humans and Nature

第18届 世界水资源大会
水与万物：人与自然和谐共生

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Content

- Background
- Methodology
- Preliminary Results

Background: Global extreme drought events

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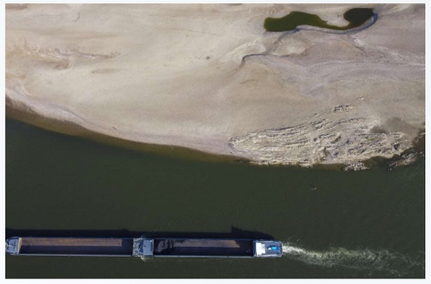
- **Global Extreme drought events are the new normal.**
- **More and more scientific evidence suggests that these events bear traces of human induced climate change**

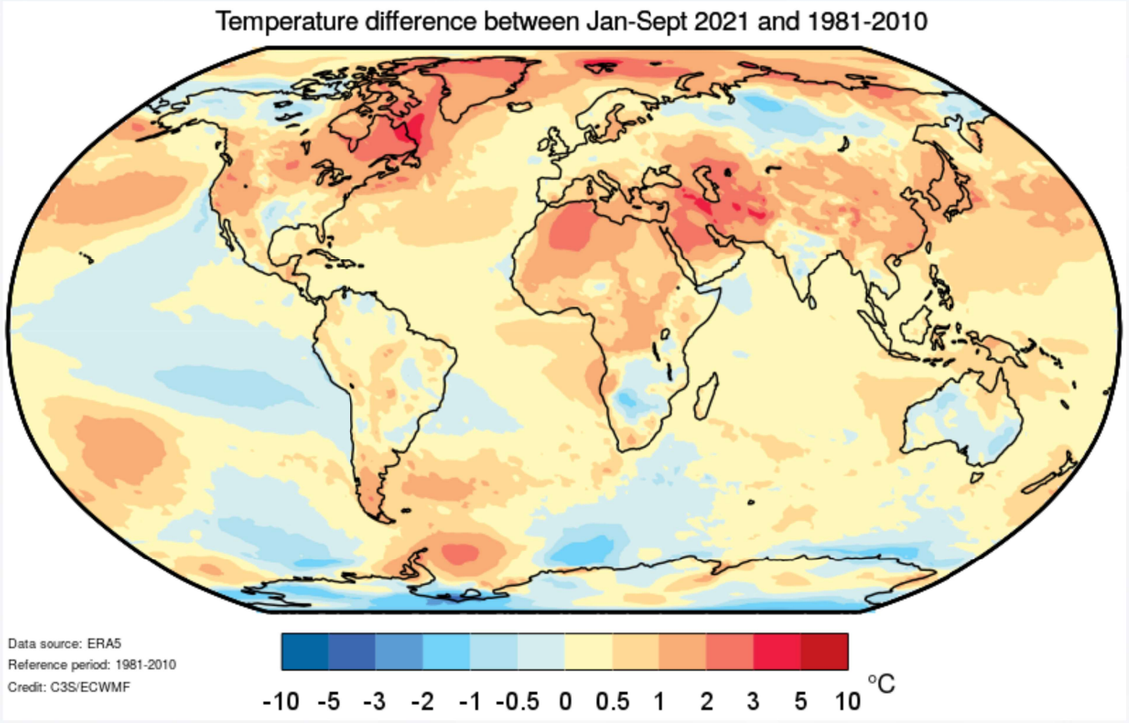
Belvedere, Belgium

Roseti, Romania

Wessel, Germany



Budapest, Hungary



The difference in near surface temperature between January to September 2021 and the average level from 1981 to 2010. The data comes from ERA5 reanalysis products.
Source: C3S/ECMWF

Background: Extreme drought events in China

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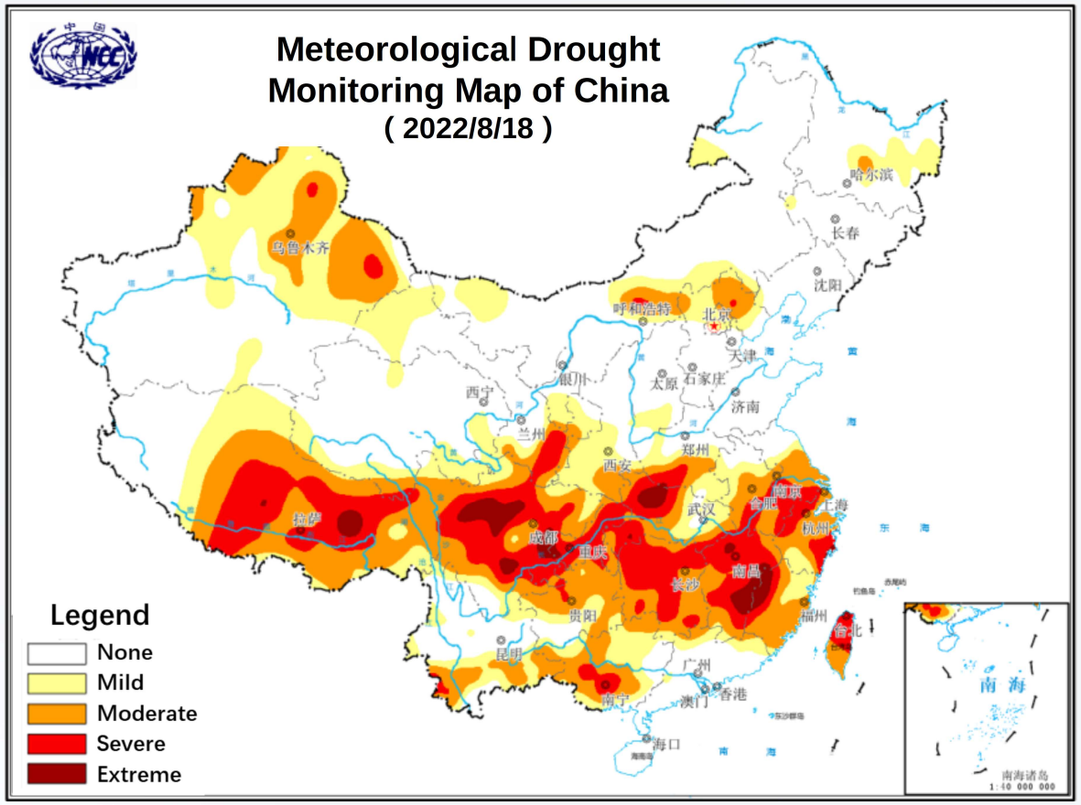
- Suffering from the extreme drought in a century, even breaking historical records.
- Focus on precise prevention and control to enhance the ability to cope with extreme drought



Source: National Climate Centre

Drying-up of Poyang lake, Jiangxi

Spring drought, Inner Mongolia

Lack of drinking water, Yunnan

Timephased water supply, Guangdong

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Methodology

- Decision makers in response to drought have conventional experience.
- Due to lack of experience in extreme drought, all measures may fail.
- In the perspective of water users, some conventional water use behaviors should be prohibited

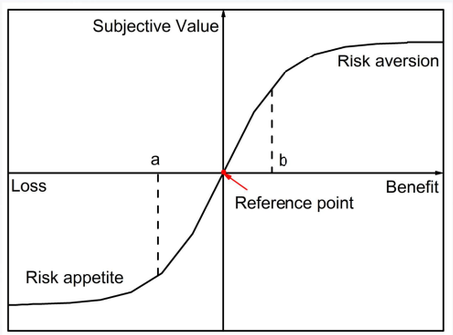
Decisions and perceptions of decision makers

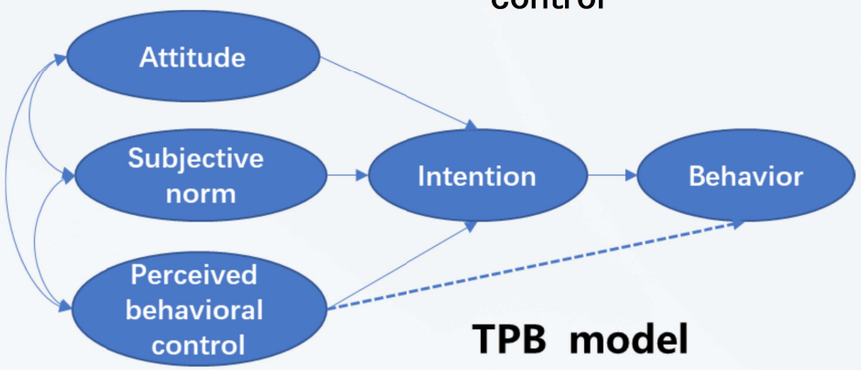
Prospect Theory + Perceived behavioral control = Planned behavior Theory

- Reference point
- Value function
- Probability weight

- Personal experience
- Expectations

- Attitude
- Subjective norm
- Perceived behavioral control





TPB model

Demands of water user

Maslow's Hierarchy of Needs Theory

- Hierarchy of needs
- Threshold of needs

Methodology

- Find the hierarchy of water needs threshold for each water users.
- Once suffering from extreme drought, we can compress some flexible water

- Household

- Industry

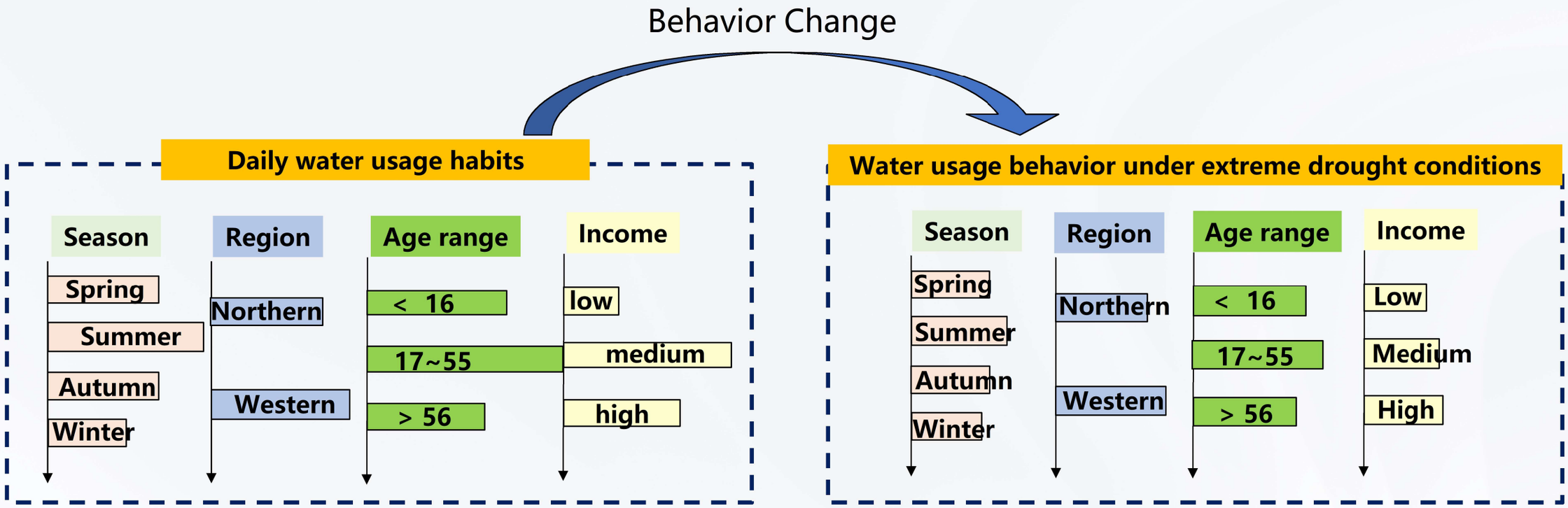
- Agriculture

- Ecology

Step1: Determining the potential influencing factors

Step2: Explaining the principles of behavior change

Step3: Determining the hierarchy of household needs and its threshold

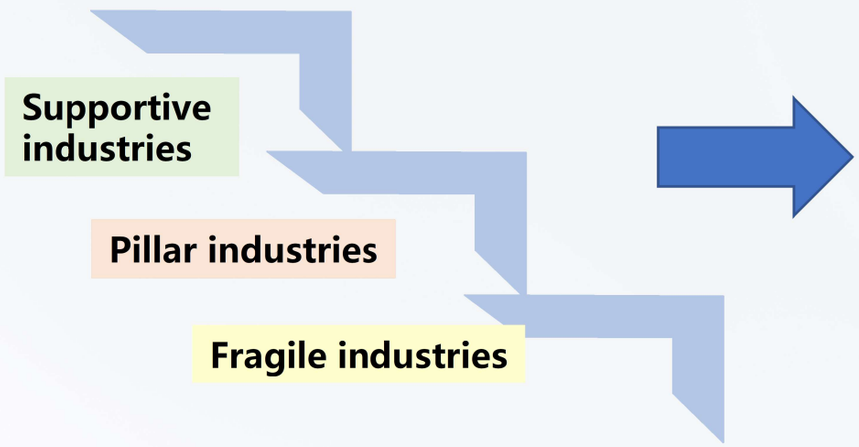


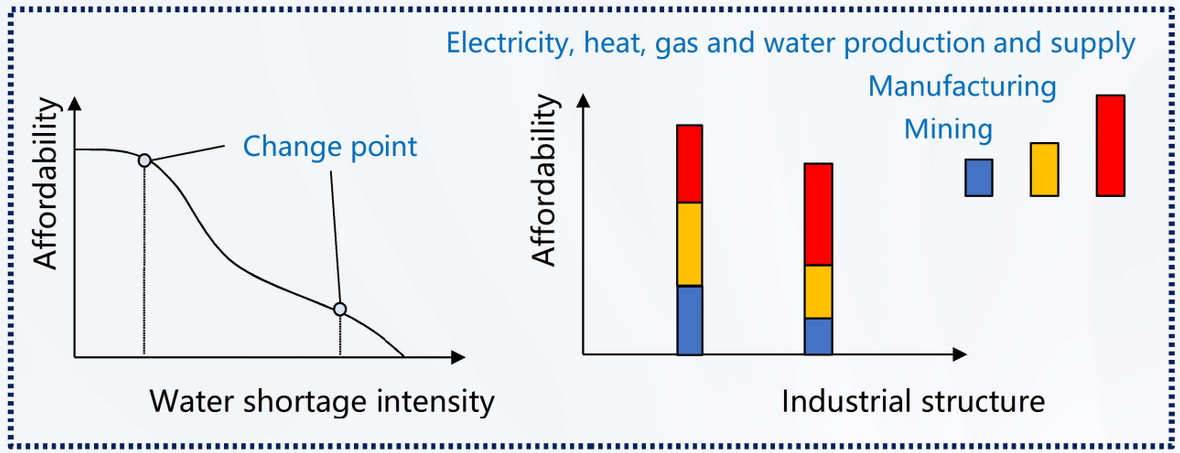
Step1: Determining the potential influencing factors

- When **dealing with short-term drought**, staged water supply for inefficient industries is an effective way.
- When dealing with long-term drought, upgrading to more water-saving processes is an effective way. (Not considered)

Step2: Ranking important industries affected by water supply

Step3: Determining the hierarchy of industrial needs and its threshold



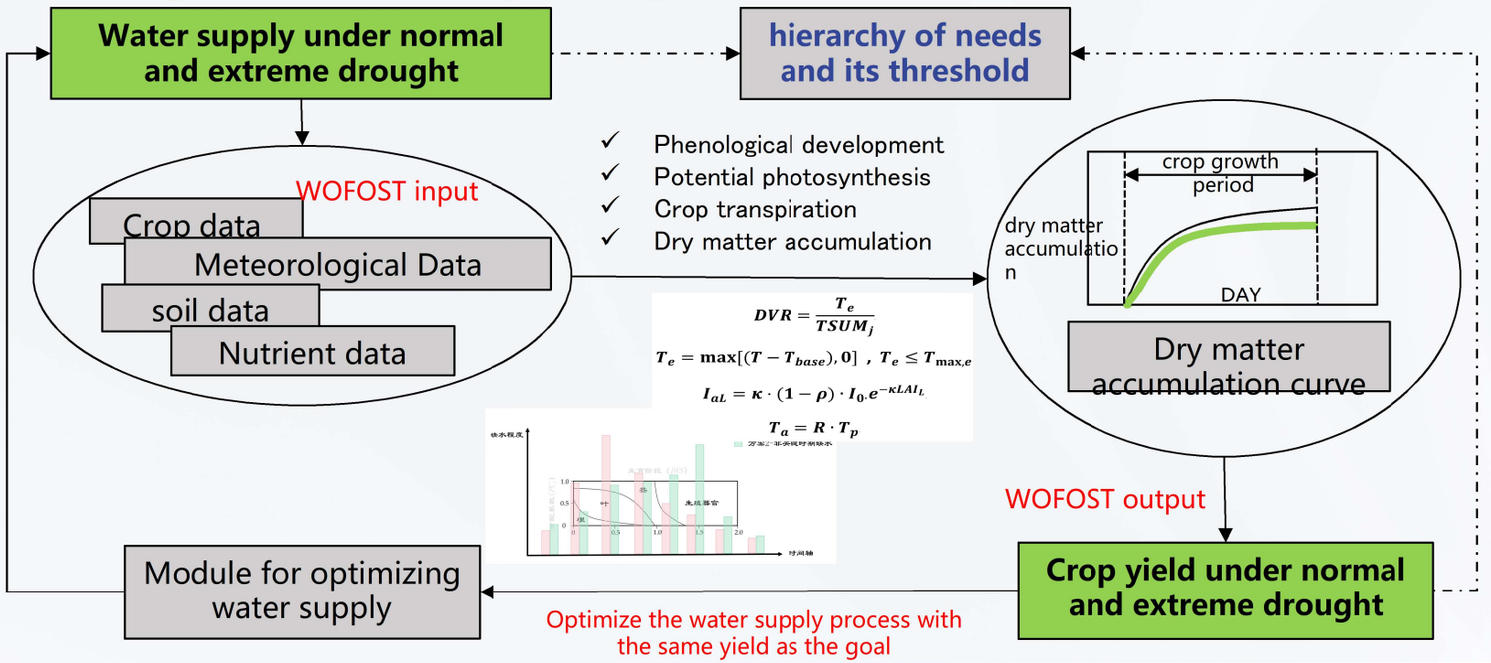


Step1: Determining the potential influencing factors

- Related to meteorological factors (eg sunshine hours, temperature, precipitation)
- Related to crop type

Step2: Simulating the relationship between water supply and crop yield

Step3: Determining the hierarchy of agricultural needs and its threshold

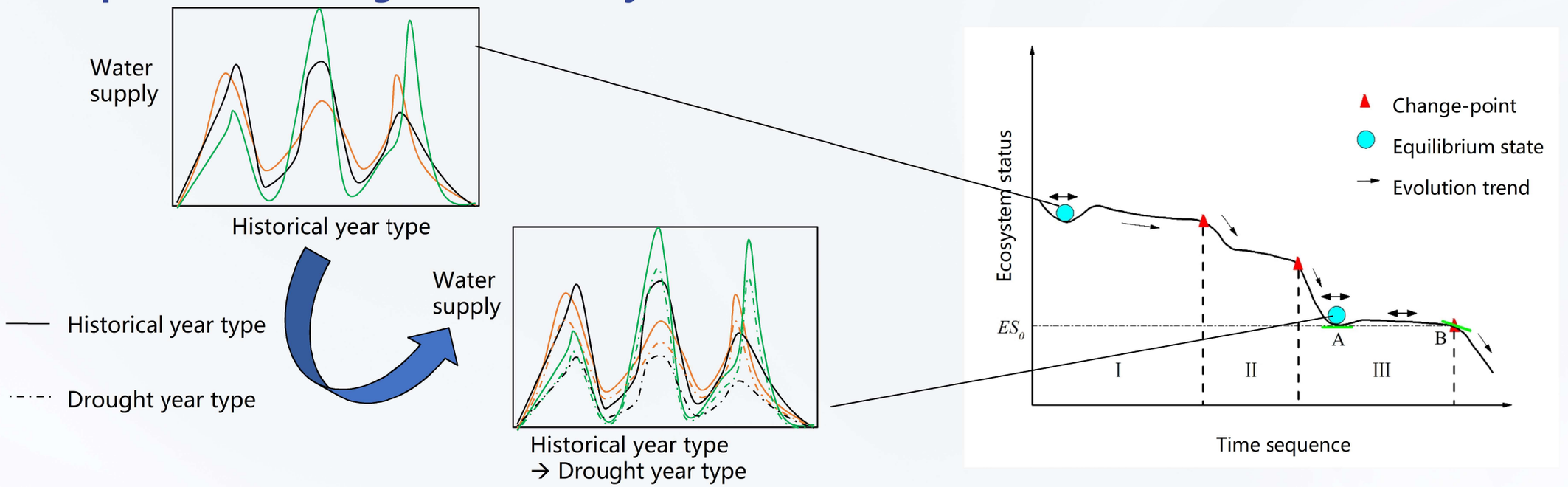


Step1: Determining the potential influencing factors

- Related to ecological types
- Related to protection targets

Step2: Explaining the principles of behavior change

Step3: Determining the hierarchy of needs and its threshold



Methodology

Water user	Might to be damaged	Strategy	Method
Household	● Life ● Quality of life	● Achieve the rigid water needs of household ● Satisfy household water willingness	Questionnaire survey &Statistical model
Industry	● Process equipment ● Economic benefits	● No damage to equipment after water shutdown ● Satisfy water users' willingness	Questionnaire survey &Statistical model
Agriculture	● Initial investment ● Crop yield	● Ensure cash crop production targets ● Ensure grain production targets	Crop yield model
Ecology	● Parts of ecological environment	● Achieve the rigid water needs of ecology ● Achieve the ecological red line	Water balance analysis &Statistical and evaluation analysis

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Preliminary Results

- Household

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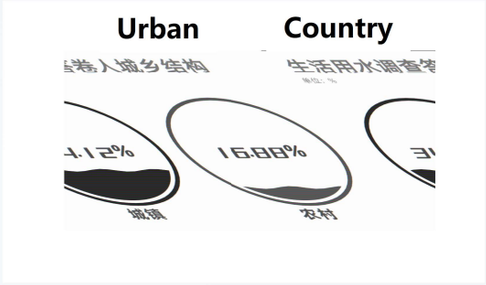
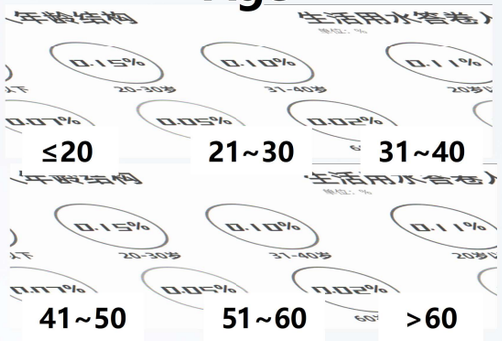
- **4169** surveys were covered by 48 questions such as basic water use information and willingness to use water under extreme conditions.
- Under extreme drought conditions, **water can be compressed by about 1/3-1/2**, with significant differences between northern and southern, as well as in summer and winter.

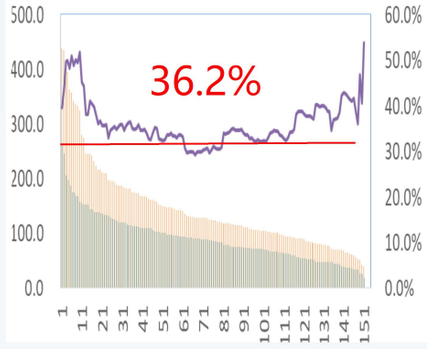
Zone

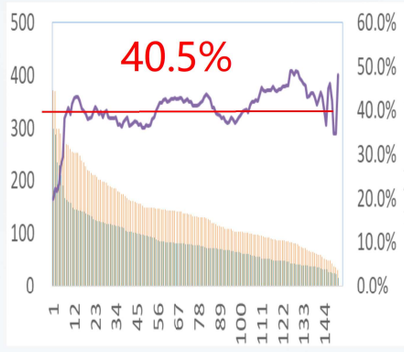


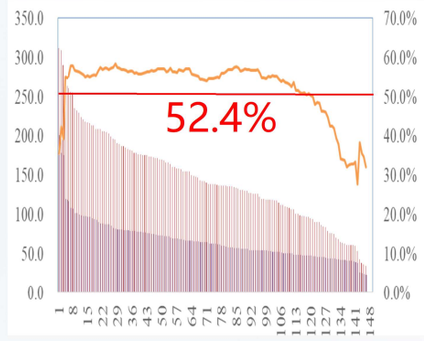
Age

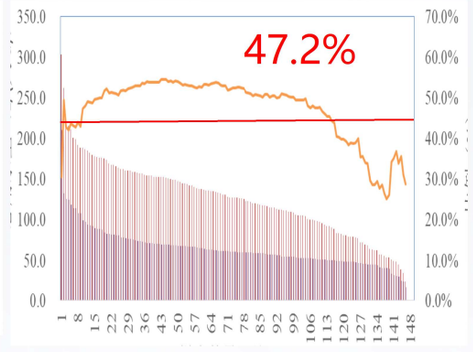


Zone	Characteristic Value	Summer water quota (L/(p·d)		Winter water quota (L/(p·d)	
		Normal	Extreme	Normal	Extreme
Western (eg. Yunan Province)	Average value	145.2	91.0	139.8	85.2
	Median	128.3	89.4	136.6	78.2
Northern (eg. Hebei Province)	Average value	146.3	67.5	126.6	64.9
	Median	138.5	62.9	127.3	60.7





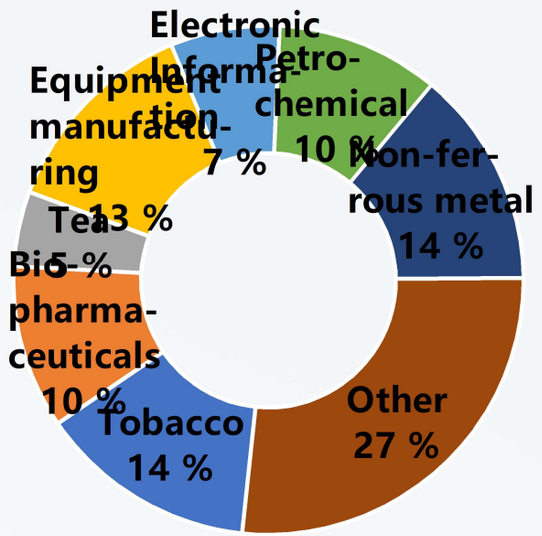


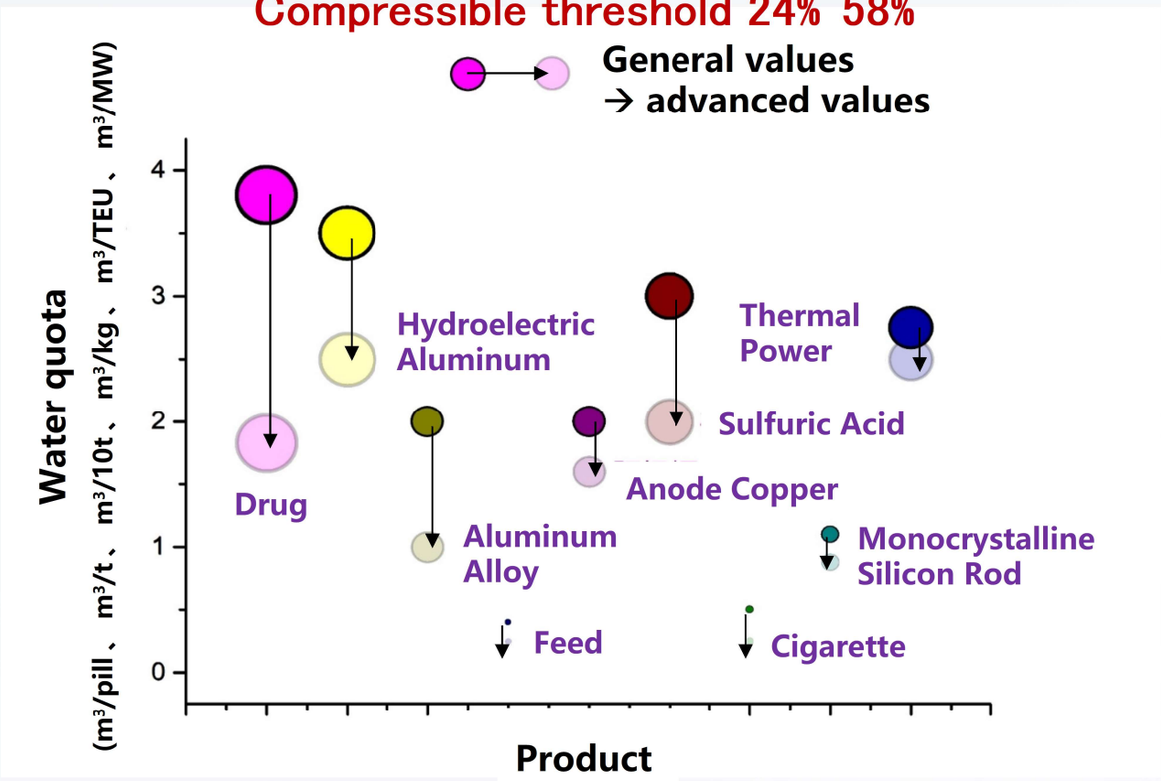


Preliminary Results

Industry

- A survey was conducted on 144 enterprises nationwide, of which 60% have no experience of water shutdown.
- Analyze the compressible amount based on the contribution rate of the industry, actual water use, and water quota of product.





Preliminary Results

Agriculture

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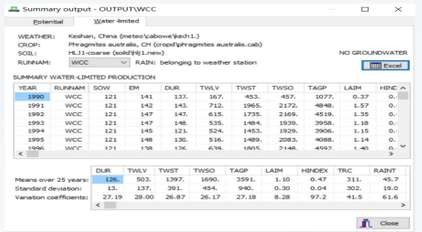
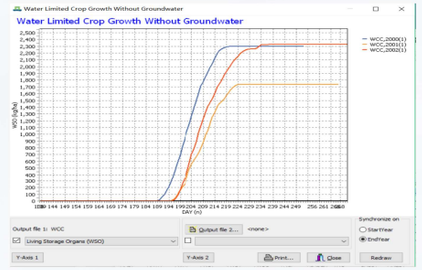
- The WOFOST model was used to simulate crop yields under historical drought years. The different water supply schemes were set for different periods. The goal was to minimize irrigation and maximize yield.
- The best plan is to irrigate 192mm and 160mm respectively during the JB stages and HF stages.

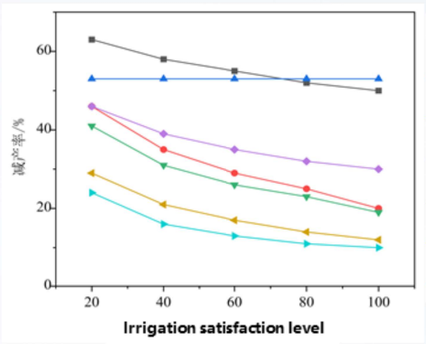




Zone	Calibraion	Validation	Flowering period		Maturity period	
			Simulated	Actual	Simulated	Actual
Chuxiong	Year 2013	Year 2014/ 2015/2017	189	187	254	253
Yuanmou	Year 2013	Year 2014/ 2016/2017	142	142	207	208
Yaoan	Year 2009	Year 2014/ 2015/2017	190	190	258	257

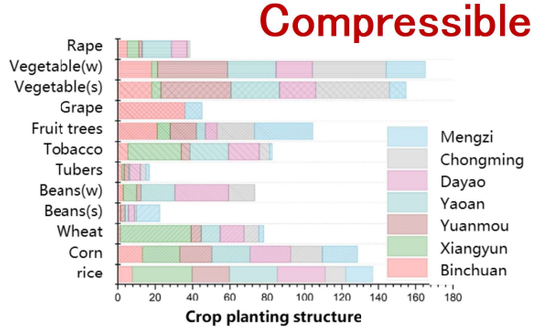
Parameter	Sensitive crop parameters		
	Chuxiong	Yuanmou	Yaoan
TSUM1/℃	1050	1270	1080
TSUM2/℃	980	1350	1000
SPAN/d	35	42	39
CVO/kg·kg^{-1}	0.503	0.526	0.488
CVS/kg·kg^{-1}	0.631	0.722	0.706

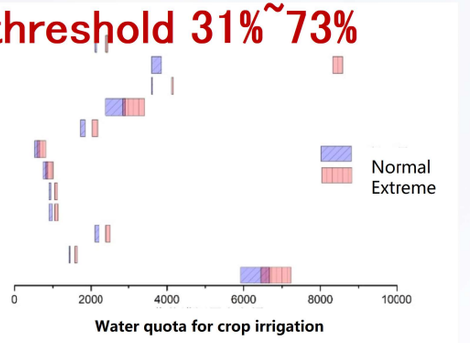
Sensitive soil parameters		
SMW	SMFCF	SMO
0.402	0.2	0.166



S1	Tillering(T)
S2	Jointing (J) and booting (B)
S3	Heading (H) and flowering(F)
S4	T+JB
S5	T+HF
S6	JB+HF
S7	T+JB+HF

Compressible threshold 31%~73%



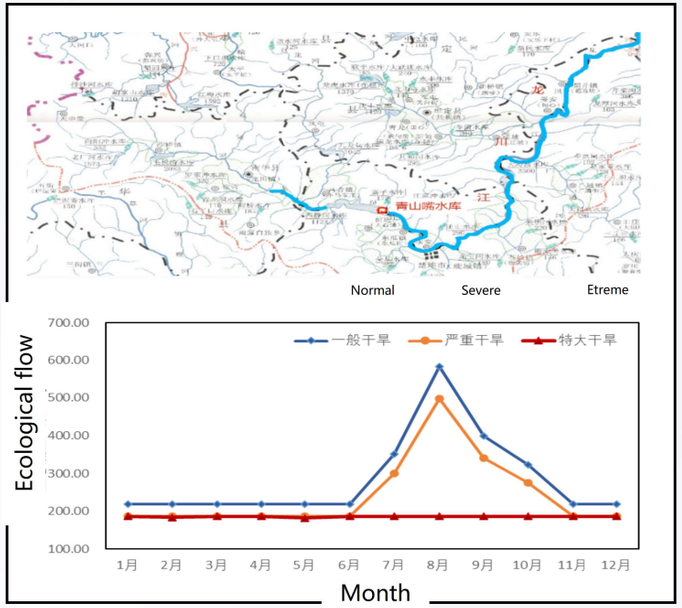


Preliminary Results

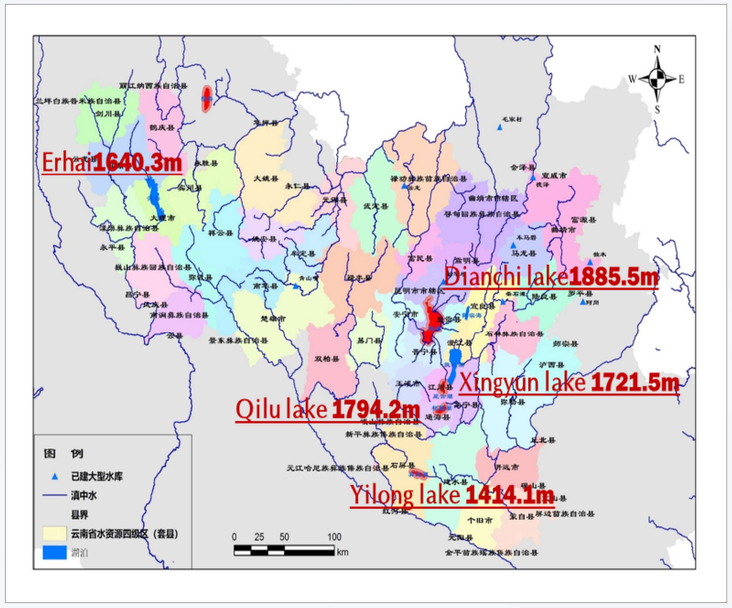
Ecology

- The Tennant method is used for the ecological flow of rivers.
- The lake ecological red line method is used to evaluate the ecological water level of lakes.
- The morphology analysis method is used to evaluate the ecological water level of wetlands.

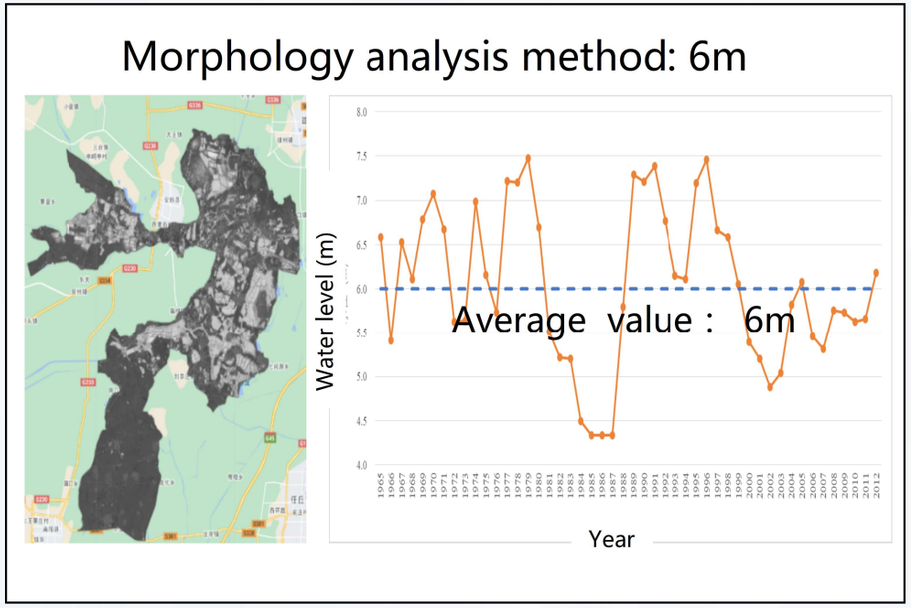
River



Lake



Wetland



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Thank you for your listening

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