

# Status of water use in agriculture and strategies on water-saving irrigation in Southwest China

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**Abstract** Water resources in southwest China are generally abundant, but its temporal and spatial distributions are not suitable to agricultural production. And many irrigation projects there have gone wrong. At the same time, a lot of water is wasted during irrigation, so there is usually a water shortage when the drought comes. This poses a grave threat to agricultural production and even to farmer's daily life. The current situation of agricultural water resources, utilization of water in agriculture and irrigation system in Southwest China was analyzed and strategies on water saving in agriculture, such as a combination of water-saving and agricultural industrialization, integration of relevant technologies, measures and policies, enhancement of R and D in water-saving, strengthening the construction of basic watering facilities and leveling fields, development and application of appropriate technologies and establishment of a good system of laws and policies were put forward in this paper.

**Key words:** Southwest China; water resource in agriculture; current situation; water saving; strategies

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## 0 Introduction

Southwest China, including Sichuan, Yunnan, Guizhou, Chongqing and Xizang, covers 2.36 million km<sup>2</sup> with a population of 194.94 million. Three mountains, Hengduan, Daboushan and Daliangshan split this area into a "triple-step": Tibet Plateau, Yungui Plateau and Sichuan Basin. Agriculture is an important sector of the economy of the region, contributing 16.7%, 21.7%, 22.2%, 25.3% and 27.0% to GDP in Chongqing, Yunnan, Sichuan, Guizhou and Tibet respectively, higher than the average of China, 15.2%<sup>[1]</sup>. However, it has been hampered by frequent droughts, ill-equipped irrigation works and ineffective utilization of water resources. Although there are some similarities between this region and the others in China regarding the issue of water use in agriculture, differences still exist. In fact, the region has fallen behind the others, such as the Northwest and the North, in using and developing rainwater harvest and water saving irrigation technologies. Relevant researches are neither profound nor widespread. One reason for this situation is that the existing technologies are not suitable to the natural characteristics and economic state of the

region. Not paying enough attention to the issue of water use in agriculture is another

## 1 Water resource and its features in Southwest China

### 1.1 Water resource

Having abundant rainfall and plenty of rivers, including the Yangtze River, the Pear River, the Yalu Tsangpo River, the Nu River, the Lanchang River and the Yuan River, Southwest China possesses 1087.2 billion m<sup>3</sup> of water resources, about 39.6% of the total of China. Table 1 shows that the region accounts for 32.2%, 40.1% and 36.1% of the total of China in the average annual precipitation, the amounts of surface water and ground water respectively. The amounts of water per capita and per hectare of cultivated land reach 263% and 208.1% respectively of the average of China.

### 1.2 Features of water resources in Southwest China

In this region, water resource is abundant, but the volume of water resources varies greatly. Firstly, rainfall is usually not evenly distributed in a year. As shown in table 2, in the three cities of the region, Kunming, Chengdu and Guiyang, the rainfall in Summer and Autumn makes up 67%~85% of the total of a whole year. There are usually droughts in spring and summer. In Sichuan, according to statistics, there was a drought every year in varying degrees from 1951 to 1995 except for 1954 and 1956<sup>[4]</sup>. In Chongqing, the frequency of drought in Spring is more than 30% and in Summer as high as 70%~

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90%. The Summer drought lasts for 20~ 30 d often, and sometimes more than 50 d<sup>[5]</sup>. While, floods occur occasionally<sup>[6,7]</sup>. Table 3 shows areas of cultivated land that were covered and affected by floods and droughts respectively in 2001. Secondly, precipitation changes greatly from year to year. Annual precipitation of some years is 2.5~ 3 times as high as that of some other years. Thirdly, some districts have more precipitation than others. For example, Guiyang got 1441.2 mm of precipitation while Lasa got only

529.7 mm in 2000. Even in the same municipality of Chongqing, the average of annual precipitations at Qianjiang and Tongnan are 1445.3 mm and 987.5 mm respectively, forming a big gap. In the Sichuan Basin, annual rainfall often varies along with the height. It can be as high as 1700 mm in some mountain regions but as low as 800 mm in some valleys. It is clear that all of these features of water resource are not suited to agricultural production.

Table 1 Water resources in Southwest China<sup>[2,3]</sup>

| Region                  | Average annual precipitation /billion m <sup>3</sup> | Surface water /billion m <sup>3</sup> | Ground water /billion m <sup>3</sup> | Total water resource /billion m <sup>3</sup> | Population     |   | Cultivated land                |   |
|-------------------------|--|---------------------------------------|--------------------------------------|--|----------------|---|--------------------------------|---|
|                         |  |                                       |                                      |  | Total /million | Water per capita /m <sup>3</sup> · person <sup>-1</sup> | Total /million hm <sup>2</sup> | Water per ha /m <sup>3</sup> · hm <sup>-2</sup> |
| Nation                  | 6188.9   | 2711.52                               | 828.77                               | 2746.03                                      | 1295           | 2120.5  | 95.67                          | 28702.2   |
| Chongqing               | 117.4  | 51.1                                  | 10.28                                | 51.1   | 30.90          | 1653.7  | 2.56                           | 19960.9   |
| Sichuan                 | 471.5  | 262.00                                | 80.16                                | 262.28                                       | 83.29          | 3149  | 6.81                           | 38514.0   |
| Guizhou                 | 209.4  | 103.50                                | 25.89                                | 103.50                                       | 35.25          | 2936  | 3.73                           | 27748.0   |
| Yunnan                  | 482.4  | 222.10                                | 73.80                                | 222.10                                       | 42.88          | 5179  | 4.74                           | 46856.5   |
| Tibet                   | 713.2  | 448.20                                | 109.43                               | 448.20                                       | 2.62           | 171068  | 0.36                           | 1245000   |
| Southwest China         | 1993.9   | 1086.9                                | 299.56                               | 1087.18                                      | 194.94         | 5577  | 18.2                           | 59735.2   |
| Southwest as % of China | 32.2   | 40.1                                  | 36.1                                 | 39.6   | 15.05          | 263.0   | 19.02                          | 208.1   |

Table 2 Percentages of seasonal precipitation at three cities in Southwest China<sup>[6]</sup>

| City    | Spring /% | Summer /% | Autumn /% | Winter /% |
|---------|-----------|-----------|-----------|-----------|
| Kunming | 11        | 60        | 25        | 4         |
| Chengdu | 16        | 63        | 18        | 4         |
| Guiyang | 29        | 47        | 20        | 4         |

Another feature of water resource in Southwest China is that though there are a lot of rivers, the cost of using this water to irrigate farmland is very high, because the land is much higher than the rivers.

Table 3 Areas covered and affected by floods and droughts in Southwest China in 2001<sup>[1]</sup>

| District  | Flood/1000 hm <sup>2</sup> |                | Drought/1000 hm <sup>2</sup> |                |
|-----------|----------------------------|----------------|------------------------------|----------------|
|           | Areas covered              | Areas affected | Areas covered                | Areas affected |
| Chongqing | 256                        | 121            | 1400                         | 698            |
| Sichuan   | 613                        | 327            | 2980                         | 1490           |
| Guizhou   | 225                        | 120            | 698                          | 333            |
| Yunnan    | 392                        | 231            | 582                          | 280            |
| Tibet     | 12                         | 10             | 23                           | 10             |

## 2 Utilization of water in agriculture and irrigation system in Southwest China

### 2.1 Status of water use in agriculture

Table 4 shows that in 1999 the agricultural sector consumed a greater part of water, as compared with the industrial and civil ones. Water used in agriculture accounted for 64.3% of the total in the whole

Southwest and 35.6%, 63.7%, 55.1%, 76.6% and 90.9% in Chongqing, Sichuan, Guizhou, Yunnan and Tibet respectively. Only in Chongqing, the percentage was lower than 50%. However, a lot of farmland is not irrigated. As shown in Table 5, the effective irrigated area and the ensured irrigated area are both small in this region. They made up only 24.41% and 12.57%, 36.26% and 25.19%, 17.52% and 14.23%, 29.61% and 17.66% and 44.74% and 17.32% of the total cultivated land area in Chongqing, Sichuan, Guizhou, Yunnan and Tibet respectively, all lower or much lower than the average level of China.

### 2.2 Status of irrigation works

#### 2.2.1 Water storage projects

There are a few large irrigation works in the Southwest. According to reference [2], among 5683 irrigated districts larger than 666.67 hm<sup>2</sup> in China, Tibet, Guizhou, Chongqing, Yunnan and Sichuan got 51, 76, 82, 191 and 254 respectively, among 141 of those between 20 km<sup>2</sup> and 33.33 km<sup>2</sup>, only Yunnan got 6, and among 101 of those larger than 33.33 km<sup>2</sup> each, only Yunnan and Sichuan got 1 and 3 respectively. Table 6 illustrates the numbers and capacity of small, medium and large reservoirs in the region. However, because most of the reservoirs were built in the 1950' - 1970' and have received little maintenance ever since then, their capacities have

decreased largely. Furthermore, some of them are in need of maintenance and repair. For example, in Chongqing, 1388 reservoirs, accounting for more than a half of the total of the municipality's 2750 reservoirs are in need of maintenance and repair, resulting in a 300 million m<sup>3</sup> decrease in storage capacity and an effect upon irrigation of more than 66667 hm<sup>2</sup> of field<sup>[8]</sup>. Besides reservoirs, there are lots of small

water storages, such as ponds, with 100 m<sup>3</sup> or so of capacity each. Constructed in recent years they are exploited to harvest rainwater and irrigate fields and play an important role when droughts come. However, their plan, arrangement, matching with other irrigating equipment and management still prove to be a problem.

**Table 4 Amount of water consumed in agricultural, industrial and civil sectors in Southwest China in 1999<sup>[2,3]</sup>**

| Region    | Total water resource /billion m <sup>3</sup> | Total consumed water /billion m <sup>3</sup> | Used in agricultural sector   |               | Used in industrial sector     |               | Used in civil sector          |               |
|-----------|--|--|-------------------------------|---------------|-------------------------------|---------------|-------------------------------|---------------|
|           |  |  | Total /billion m <sup>3</sup> | Proportion /% | Total /billion m <sup>3</sup> | Proportion /% | Total /billion m <sup>3</sup> | Proportion /% |
| Total     | 1087.18                                      | 52.28  | 33.611                        | 64.3          | 11.443                        | 21.9          | 7.226                         | 13.8          |
| Chongqing | 51.1   | 5.517  | 1.963                         | 35.6          | 2.352                         | 42.6          | 1.202                         | 21.8          |
| Sichuan   | 262.28                                       | 20.638                                       | 13.141                        | 63.7          | 4.868                         | 23.6          | 2.629                         | 12.7          |
| Guizhou   | 103.5  | 8.769  | 4.833                         | 55.1          | 2.408                         | 27.5          | 1.528                         | 17.4          |
| Yunnan    | 222.1  | 14.787                                       | 11.329                        | 76.6          | 1.749                         | 11.8          | 1.709                         | 11.6          |
| Tibet     | 448.2  | 2.579  | 2.345                         | 90.9          | 0.066                         | 2.6           | 0.168                         | 6.5           |

**Table 5 Effective and ensured irrigated areas in Southwest China in 2000<sup>[2]</sup>**

| Region    | Cultivated land area /k hm <sup>2</sup> | Effective irrigated area |                               | Ensured irrigated area   |                               |
|-----------|---|--------------------------|-------------------------------|--------------------------|-------------------------------|
|           |   | Total /k hm <sup>2</sup> | Percent as cultivated land /% | Total /k hm <sup>2</sup> | Percent as cultivated land /% |
| Nation    | 95673                                   | 55013.15                 | 57.50                         | 40164.26                 | 41.98                         |
| Chongqing | 2560                                    | 624.77                   | 24.41                         | 321.78                   | 12.57                         |
| Sichuan   | 6810                                    | 2468.99                  | 36.26                         | 1715.25                  | 25.19                         |
| Guizhou   | 3730                                    | 653.37                   | 17.52                         | 530.72                   | 14.23                         |
| Yunnan    | 4740                                    | 1403.40                  | 29.61                         | 836.94                   | 17.66                         |
| Tibet     | 360                                     | 161.07                   | 44.74                         | 62.35                    | 17.32                         |

**Table 6 Number of reservoirs in Southwest China in 2000<sup>[2]</sup>**

| Region    | Total        |                                  | Large reservoir |                                  | Medium reservoir |                                  | Small reservoir |                                  |
|-----------|--------------|----------------------------------|-----------------|----------------------------------|------------------|----------------------------------|-----------------|----------------------------------|
|           | number /unit | capacity /million m <sup>3</sup> | number /unit    | capacity /million m <sup>3</sup> | number /unit     | capacity /million m <sup>3</sup> | number /unit    | capacity /million m <sup>3</sup> |
| Nation    | 85120        | 518357.64                        | 420             | 384281.39                        | 2704             | 74639.04                         | 81996           | 59437.21                         |
| Chongqing | 2730         | 3694.60                          | 3               | 1500.47                          | 33               | 653.48                           | 2694            | 1540.65                          |
| Sichuan   | 6657         | 8758.04                          | 5               | 2574.70                          | 95               | 2456.18                          | 6557            | 3727.16                          |
| Guizhou   | 1927         | 7442.33                          | 7               | 4797.24                          | 50               | 1283.16                          | 1870            | 1361.93                          |
| Yunnan    | 5178         | 8314.98                          | 3               | 877.60                           | 145              | 4245.22                          | 5030            | 3192.16                          |
| Tibet     | 47           | 1024.26                          | 2               | 821.00                           | 2                | 162.00                           | 43              | 41.26                            |

Note: The capacity of the large reservoir is over 100 million cubic meters, the medium is from 10 million to 100 million cubic meters, and the small is from 100 000 to 10 million cubic meters.

### 2.2.2 Water pumps and pumping stations

As shown in Table 7, the Southwest China has a large number of pumping stations. In addition, there are a lot of smaller pumps powered by engines or motors. Pumps are very important for the agriculture in this region, especially in mountainous and hilly areas and when there is an extraordinarily serious drought and reservoirs and ponds dry up. In Sichuan, pumps generally supply 40 billion m<sup>3</sup> of water annually for irrigating and ensure irrigation of 1 million hm<sup>2</sup> of field, 933.33 km<sup>2</sup> of which are paddy field. That accounts for about 40% of the province total area of paddy fields, and two-thirds of paddy fields there in hilly areas are irrigated with pumps<sup>[9]</sup>. In Chongqing,

70% of the total effective irrigated areas were watered by pumps in 2002. However, being old and lacking in maintenance most of them consume oil or electricity much more than the standard and are inefficient and unsafe. Although considerable headway has been made in renovating pumping stations since 1980<sup>'</sup>, the task is far from being finished. For example, according to statistics, nearly a half of pumping equipment in Sichuan have been used for more than 15 years and one-third of those have worked longer than they should and are now inefficient. Motors, pumps and transformers made in 1950<sup>'</sup> - 1960<sup>'</sup> should be eliminated, but are still used in many key pumping stations<sup>[9]</sup>. As many as 74.1 thousand pumping

equipments in Chongqing are planned to be repaired or renovated in 2004. After 370 thousand pumping equipment being repaired in the "Ninth Five-year Plan" in Sichuan, two kinds of pumping stations are wanted to be renovated in separate batches in the

"Tenth Five-year Plan" in Sichuan. One is those with 100 kW of power each, 866 in all, and the other is those which have 1000 kW of power each and can cover 666 67 hm<sup>2</sup> of fields<sup>[9]</sup>.

Table 7 Number of farming pumps and pumping stations in Southwest China in 2000<sup>[2]</sup>

| Region    | Possession of irrigation and drainage machinery /MW | Farming pump /kilo-unit | Pump station |         | Electrical motor powered drainage and irrigation station |         | Diesel engine powered drainage and irrigation station |        |
|-----------|---|-------------------------|--------------|---------|--|---------|---|--------|
|           |   |                         | /unit        | /MW     | /unit  | /MW     | /unit   | /MW    |
| Nation    | 41569.7   | 1633.65                 | 506067       | 21798.4 | 423786   | 20017.3 | 82281   | 1781.1 |
| Chongqing | 352.7   | 22.83                   | 7609         | 301.5   | 7456   | 298.4   | 153   | 3.1    |
| Sichuan   | 1564.0  | 38.78                   | 29323        | 1054.8  | 26992  | 1028.4  | 2331  | 26.4   |
| Guizhou   | 315.4   | 9.11                    | 7969         | 208.1   | 6935   | 189.8   | 1034  | 18.3   |
| Yunnan    | 728.4   | 8.88                    | 12696        | 651.8   | 12155  | 644.0   | 514   | 7.8    |

### 2.2.3 Ditches and pipes

There are various ditches and pipes in irrigating systems in Southwest China, of which soil ditches, stone ditches and cement ditches make up a large part. Damage, seepage and ill matching of ditches are found commonly. For example, in Chongqing, 6200 km of ditches have not matched with other water conservancy facilities; and no measures have been taken to prevent water seeping out of 3800 km of ditches. In addition, a lot of water is lost through vaporization. The average water availability of the canal system is 0.31, 0.34, 0.35, 0.40 and 0.44 in Xizang, Yunnan, Guizhou, Sichuan and Chongqing respectively<sup>[3]</sup>. And more than 55% ~ 69% of water is lost during the transportation<sup>[10,11]</sup>.

### 2.3 Application of irrigation technologies

In recent years, various technologies of water-saving irrigation have been developed and adopted in China. Table 8 lists the areas and percentages associated with some of those technologies of the Southwest and of China in 2000, and those where the technologies were applied best in China. Except Guizhou, the other parts of the Southwest still mainly used traditional irrigation methods. Compared with the average level of China, the region lagged far behind in applying advanced water-saving irrigation technologies, especially low pressure pipe irrigation and sprinkler irrigation. Only in respect of canal seepage control Yunnan, Sichuan and Guizhou exceeded the average level of China. It is quite evident that there existed a big gap between Southwest China and those advanced areas in applying the technologies.

Table 8 Areas and percentages associated with water-saving irrigation technologies of Southwest China in 2000<sup>[2]</sup>

| Region                 | Valid irrigation area /km <sup>2</sup> | Traditional irrigation |                                      | Canal seepage control |                                      | Low pressure piping   |                                      | Sprinkler irrigation  |                                      | Micro-irrigation      |                                      | Other irrigation      |                                      |
|------------------------|--|------------------------|--------------------------------------|-----------------------|--------------------------------------|-----------------------|--------------------------------------|-----------------------|--------------------------------------|-----------------------|--------------------------------------|-----------------------|--------------------------------------|
|                        |  | Area /km <sup>2</sup>  | Percentages of valid irrigation area | Area /km <sup>2</sup> | Percentages of valid irrigation area | Area /km <sup>2</sup> | Percentages of valid irrigation area | Area /km <sup>2</sup> | Percentages of valid irrigation area | Area /km <sup>2</sup> | Percentages of valid irrigation area | Area /km <sup>2</sup> | Percentages of valid irrigation area |
| Nation                 | 55013.15                               | 38624.29               | 70.21                                | 6361.33               | 11.56                                | 3567.92               | 6.49                                 | 2131.4                | 3.87                                 | 152.58                | 0.28                                 | 4175.63               | 7.59                                 |
| Chongqing              | 624.77                                 | 574.94                 | 92.03                                | 36.42                 | 5.83                                 | 6.34                  | 1.01                                 | 1.3                   | 0.21                                 | 0.07                  | 0.01                                 | 5.7                   | 0.91                                 |
| Sichuan                | 2468.99                                | 1780.48                | 72.11                                | 620.27                | 25.12                                | 13.02                 | 0.53                                 | 23.21                 | 0.94                                 | 3.63                  | 0.15                                 | 28.38                 | 1.15                                 |
| Guizhou                | 653.37                                 | 360.95                 | 55.24                                | 181.63                | 27.8                                 | 14.83                 | 2.27                                 | 3.54                  | 0.54                                 | 6.07                  | 0.93                                 | 86.35                 | 13.22                                |
| Yunnan                 | 1403.40                                | 1149.24                | 81.89                                | 185.4                 | 13.21                                | 17.73                 | 1.264                                | 1.03                  | 0.07                                 | 0.93                  | 0.066                                | 49.07                 | 3.5                                  |
| Tibet                  | 161.07                                 | 146.67                 | 91.06                                | 14.16                 | 8.79                                 | —                     | —                                    | 0.17                  | 0.11                                 | —                     | —                                    | 0.07                  | 0.04                                 |
| Highest level of China | —                                      | 106.3                  | 37.18                                | 1352.09               | 42.23                                | 153.40                | 53.66                                | 300.48                | 14.79                                | 18.65                 | 1.42                                 | —                     | —                                    |
|                        |  | Shanghai               | Shanghai                             | Xinjiang              | Xinjiang                             | Shanghai              | Shanghai                             | Heilongjiang          | Heilongjiang                         | Shanxi                | Shanxi                               |                       |                                      |

### 2.4 Irrigation schedules

The shortage of rational irrigation schedules for different crops, soils, climates, irrigation technologies, management and economic situations is another big problem which the Southwest met. Traditional irrigation schedules, or irrigation schedules by experience are applied commonly in the region, even where water-saving equipment is in use.

### 2.5 Management of irrigation system

There are mainly three problems in the management of irrigation systems in the Southwest to be solved. The first one is that the price of water used for irrigation is not fair. Generally, now the practical price is equal to only two-thirds of the cost. This places management in a difficult position and hampers the efficient use of water. The second one is that relevant government departments, such as those involved with water conservancy, agriculture,

agricultural machinery and science and technology have not fully cooperated in spreading water-saving technologies, nor have researchers of relevant fields. As a result, relevant water-saving technologies have not been well-matched in the region. The last one is that there is a big gap between what the government and researchers suggest farmers to do in using water and what the farmers are willing to adopt.

### 3 Measures to promote water-saving irrigation in Southwest China

#### 3.1 Combination of water-saving and agriculture industrialization<sup>[12-15]</sup>

For China joining WTO and the adjustment of rural economic structure, water saving technology and measures should be developed and spreaded through the selection and development of superior agricultural industries. By this way, the technology and measures can be popularized better and faster.

#### 3.2 Integration of relevant technologies for water-saving<sup>[4, 15-19]</sup>

Various relevant technologies, as well as measures and policies should be integrated in line with the local conditions to improve water conservation. There are many opportunities to do this. For example, by taking advantage of the region abundant rainfall, mountainous and hilly topography, various species of crops and other plants and so on, each of the following groups can be well integrated: harvesting rainwater and pumping water from rivers and ponds<sup>[20]</sup>; new water conservancy facilities and old ones; non-powered irrigation and powered one; water-saving technology and energy-saving technology<sup>[21]</sup>; different relevant measures, such as those by engineering, agriculture and organism; and technologies, management and policies.

#### 3.3 Enhancement of R and D in water-saving<sup>[14, 22-25]</sup>

R&D in water-saving must be enhanced particularly in the following fields: water-saving measures by engineering, agriculture and organism, especially those with high technology, rational irrigation schedules to different conditions, application of the information technology in design and amelioration of irrigation systems, feasible regulations of building water-saving irrigation facilities and management of irrigation systems.

#### 3.4 Strengthening basic construction<sup>[9, 17, 26-28]</sup>

Construction of basic water conservancy facilities, such as reservoirs, ponds, pumping stations, ditches and pipes and transformation of and leveling fields

should be strengthened.

#### 3.5 Development and application of appropriate technologies<sup>[22, 29]</sup>

It should be emphasized to develop, popularize and apply appropriate water-saving technologies, equipment, measures, computer software and so on in line with the local conditions.

#### 3.6 Establishment of a good system of laws and policies for water-saving<sup>[30, 31]</sup>

It is important to establish a good and well-matched system of laws and policies in accordance with the local conditions, because rational prices of irrigated water can encourage investment and innovation in water-saving and application of technologies and measures of water-saving in the region.

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## 中国西南地区农业水资源利用现状及对策

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**摘要:** 西南地区总体上虽然水资源丰富, 但其时空分布不适宜于农业生产。很多灌溉设施不能正常工作。与此同时, 大量的水资源在灌溉过程中被浪费掉, 因而一遇干旱, 这一地区便常常缺水, 这对农业生产乃至农民生活构成严峻威胁。本文分析了这一地区水资源及其在农业上的利用以及农业灌溉系统的现状, 提出了节水灌溉与农业产业化相结合, 集成相关技术、措施与政策, 加强节水领域的研究与开发工作, 加快建设水利基础设施与平整土地, 开发和应用适用技术以及建立良好的法规政策体系等对策。

**关键词:** 西南地区; 农业水资源; 现状; 节水; 对策