

Review

Strategic considerations for Chinese agricultural water and food safety: Issues, challenges and suggestions

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China is a country not only with water resources shortage, but also with a large population and great food needs. Food security issues have aroused great concern at home and abroad. It has become an inevitable choice for sustainable development of Chinese economic society to achieve food and strategic water security. Based on related analysis of current data as agricultural water consumption, effective irrigation, food production and cultivation areas in China from 1949 – 2006 and the achievements as well as key challenges facing the Chinese grain production were discussed from the view of protecting Chinese recent and medium food and strategic water security. It is proposed that the solution to this crucial hard problem lies on vigorously developing modern water-saving high-efficient agriculture and relying on technology. It is believed that under the premise of ensuring Chinese future strategic water security, the water needs of Chinese food security can basically be met. Based on the above, it is put forward that Chinese recent medium water-saving and high-efficient agriculture research should put emphasis on five aspects, which include the biological water-saving technology, inferior water resources development technology, high-efficient water using technology for dry farming, water-saving irrigation technology and equipments, as well as regional high-efficient water-saving agriculture comprehensive technology.

Key words: Agricultural water, food safety, water-saving potential, research emphasis.

INTRODUCTION

China is a nation with short per capita water resources and uneven time-space distribution. The per capita water resource is only 1/4 of the world level. The largest rainfall in four months accounts for about 70% of the total annual rainfall in most region of China, while the drainage area in the North of the Yangtze River accounts for 64% total landmass. However, the water resource only accounts for 19% of the whole country. Drought and water shortage have become a bottleneck for Chinese economic and social sustainable development. With the population increase and rapid development of urbanization and economic society, Chinese water conflicts are increasingly acute and strategic water security issues are more serious (Sci-Technology Ministry, Rural Sci-Technology Department and China Rural Technology Develop Centre, 2006; Wu, 2006a).

Meanwhile, China is a great agricultural country with the largest population and food consumption in the world;

the food security issues have become so particular in China. It has become the key for Chinese food safety to produce food to meet the majority needs relying on own resources and it also attracted great attention at home and abroad. As early as 1994, Senior Fellow Lester Brown, the U.S. director of the World Watch, asserted in "Who will feed Chinese people in the next century" that China's population will reach its peak in 2030 and the import food will be significantly more than the total world export food. As a result, the Chinese will make the world suffer from hunger. Such an assertion, no doubt, proposed a piece of advice for Chinese food security strategy from a rational point of view. International Water Research Institute (IWMI) and the International Food Policy Research Institute (FPRI) have also expressed great concern about Chinese water shortages and food security issues (Liao and Huang, 2004; Shi and Lu, 2001). Chinese agriculture development is at a critical

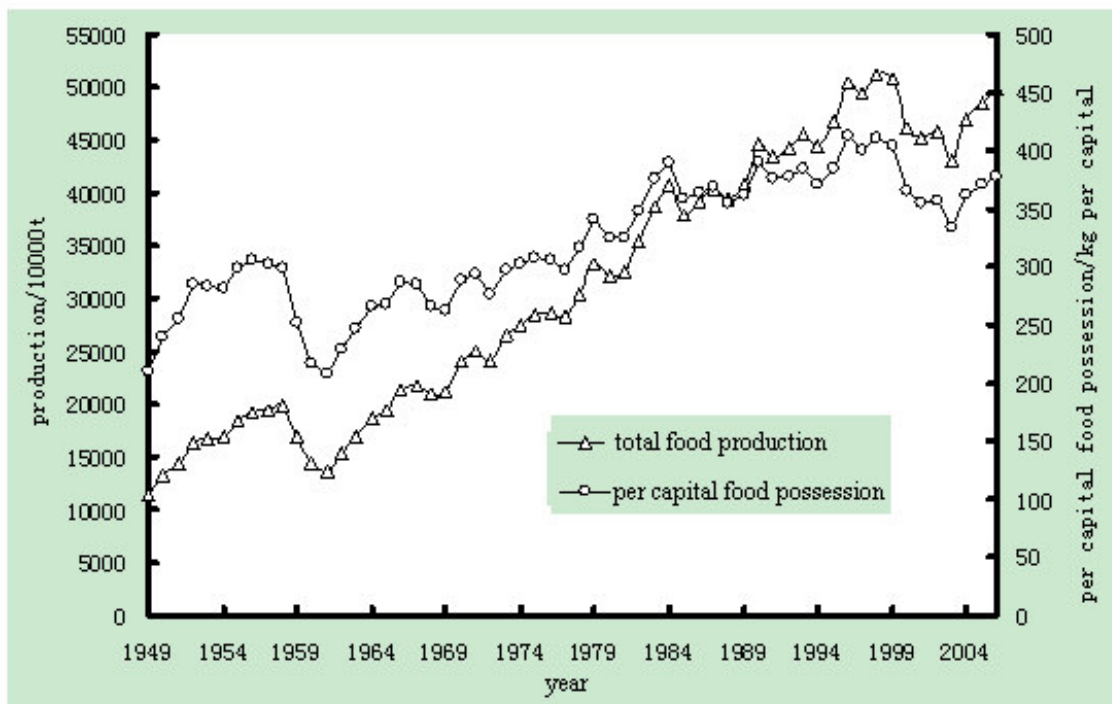


Figure 1. The situation of total food production and per capita food possession over the years in China.

period with the traditional technology intertwined with the high-tech development; that is, how it can meet food needs of future increasing population by the limited water resources has become a problem that need to be urgently discussed and gradually put into practice. Based on the analysis of agricultural water, food production and other basic data in China over the years, this paper discussed the achievements and key challenges facing the Chinese grain production from the view of protecting Chinese recent and medium food security and strategic water security. Also, it proposed corresponding technical measures to solve facing key challenges, in order to provide an important reference for ensuring food security during the population peak and solving conflicts between Chinese future agricultural water and food production.

THE ANALYSIS OF CHINESE FOOD PRODUCTION STATUS

China is the greatest developing country in the world and its food safety issues make great influences on that of the world. After the 1950s, Chinese government worked at agriculture producing development to increase the production and supplying levels of food production and constantly reinforced its own food safety ability.

National statistics show that (Figure 1), during the half century of 1949-2006, Chinese total food production increased from 113.18 million t in 1949 to 497.36 million t in 2006, raised 3.4 times. At the same period, the total

world food production increased from 890 million t to 2.142 billion t, raised 1.4 times. Over half a century, Chinese grain has consecutively jumped four steps by 100 million t level from 113.18 million t in 1949 to 505.45 million t in 1996, 200 million t (1958), 304.76 million t (1978), 404.73 million t (1987) and reached a highest-ever level of 512.29 million t in 1998 (National Statistics Bureau Rural Social and Economic Investigation Division, 2006 a,b). Chinese population increased from 542 million in 1949 to 1.315 billion in 2006 based on the population increment of 2.4 times. China has achieved the ability that per capita grain possession exceeds the world average level (342 kg) after half a century effort. The per capita grain possession was raised from 208.9 kg in 1949 to 378 kg in 2006, in which, 1996 reached the highest level (414.1 kg) and maintained per capita level above 400 kg for four consecutive years. Analysis shows that Chinese grain production has basically achieved the historical leaps that transforms from long-term shortage to basic total balance and have extra food in abundant years. The proportion of Chinese total grain production in that of the world is constantly rising, which will have a pivotal role in the world's food production.

To raise land productivity is the key point to increase effective food supply for China with short land resources and large population. From Figures 2 and 3, it can be seen that over the half century, Chinese grain production increment is not primarily achieved by the expansion of planting area, but by increasing per unit area production through a variety of technical measures. Chinese grain

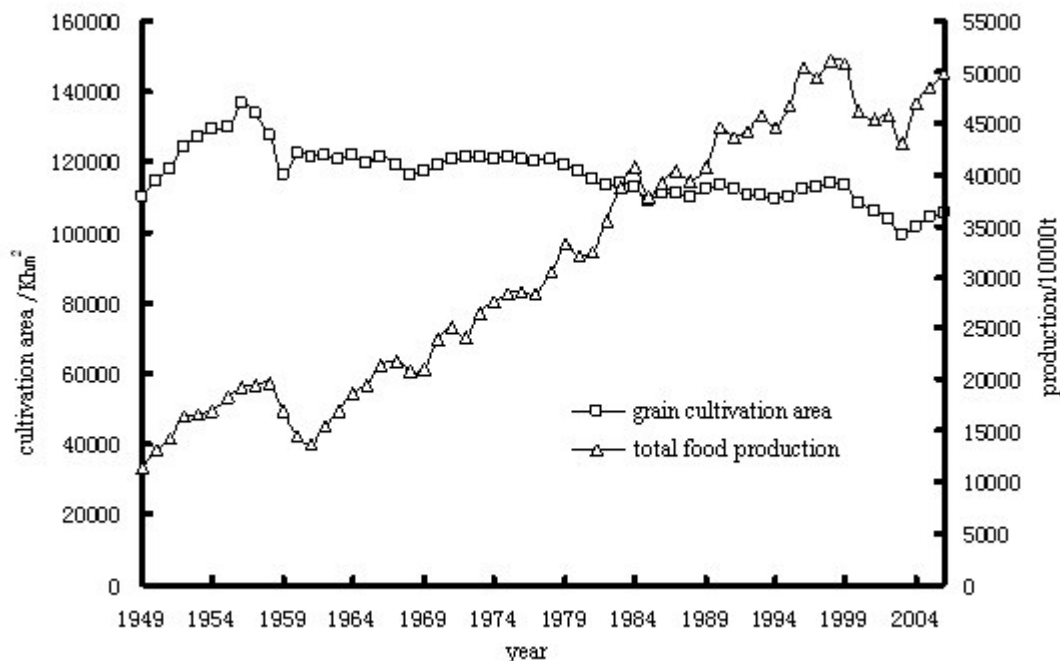


Figure 2. The situation of grain cultivation area and total food production over the years in China.

cultivated area declined largely in the past 50 years and ranged at 109.93-125.52 million hm². The average grain cultivated area in 1990s reduced by 13.625 million hm² than that of 1950s with a decrease of 10.9%, while the grain yield in 1990s increased by 2698 kg/hm² than that of 1950s with an increase of 196.6% (National Statistics Bureau Rural Social and Economic Investigation Division, 2006 a,b). The grain yield increase amplitude is larger than the area decrease amplitude, which is the basement for Chinese total grain production jump in the half century.

THE ANALYSIS OF CHINESE AGRICULTURAL WATER USING STATUS

Total water supply largely increases, while water using structure becomes more rational and the proportion of agricultural water decreases year by year.

Water is the lifeblood of agriculture and agriculture is the basis for national economic development. The increment of food production level can not be discussed without water, so water plays an irreplaceable role in raising food production level. China began to vigorously exploit water resources and develop irrigation since 1950s and a tremendous achievement has been made in 2005. The national total water supply capacity (579.5 billion m³) accounts for 22.9% of national water resource, in which the amount of surface water supply is 470.68 billion m³. The amount of underground water supply is 106.55 billion m³ and that of other sources supply is 2.27 billion m³. Among the surface water supply, the supply of storage, directing and lifting projects, respectively, acco-

unt for 34.5, 37.1 and 0.44% of the total supply. Among underground water supply, the supply of phreatic, deep confined and brackish waters, respectively, account for 80.5, 19.0 and 0.5% of the total supply.

Among other sources supply, the amount of reused treated sewage is 1.29 billion m³, the amount of rainwater harvesting projects is 970 million m³ and the amount of desalinated seawater is 10 million m³. However, with the continuing population growth, the national total water consumption which is also increasing was 579.5 billion in 2006, among which domestic water accounts for 12.0%, industrial water, 23.2%, agricultural water, 63.2% and ecology and environment replenishment (including only the water supplied to urban environment through artificial measures and the water replenishment by a part of lake and wetland), 1.6% (The preparing group for water resource bulletin of PRC water resource ministry, 2007). From Chinese water using situations over the years (Figure 4), it can be seen that Chinese total water consumption increased from more than 100 billion m³ in 1949 to 579.5 billion m³ in 2006 and agricultural water consumption increased from 100.11 billion m³ in 1949 to 366.44 billion m³ in 2006, among which irrigation water also increased to 330.53 billion m³. At the same time, the contradictions between agriculture, industrial and eco-environmental waters is increasingly more acute and with the application of water-saving irrigation technology in the past 20 years, the proportion of agricultural water showed a decreasing trend, that is, decreased from 90% in 1949 to the current 63.2% and the water using structure gradually transformed to a reasonable direction.

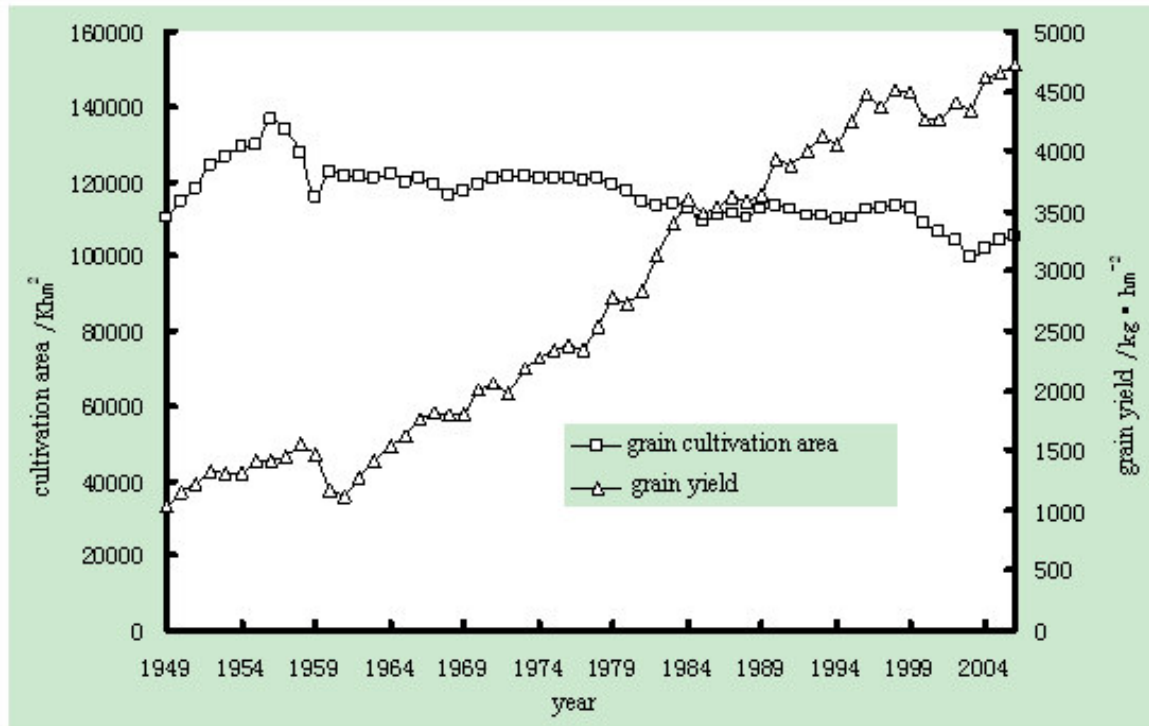


Figure 3. The situation of grain cultivation area and grain yield over the years in China.

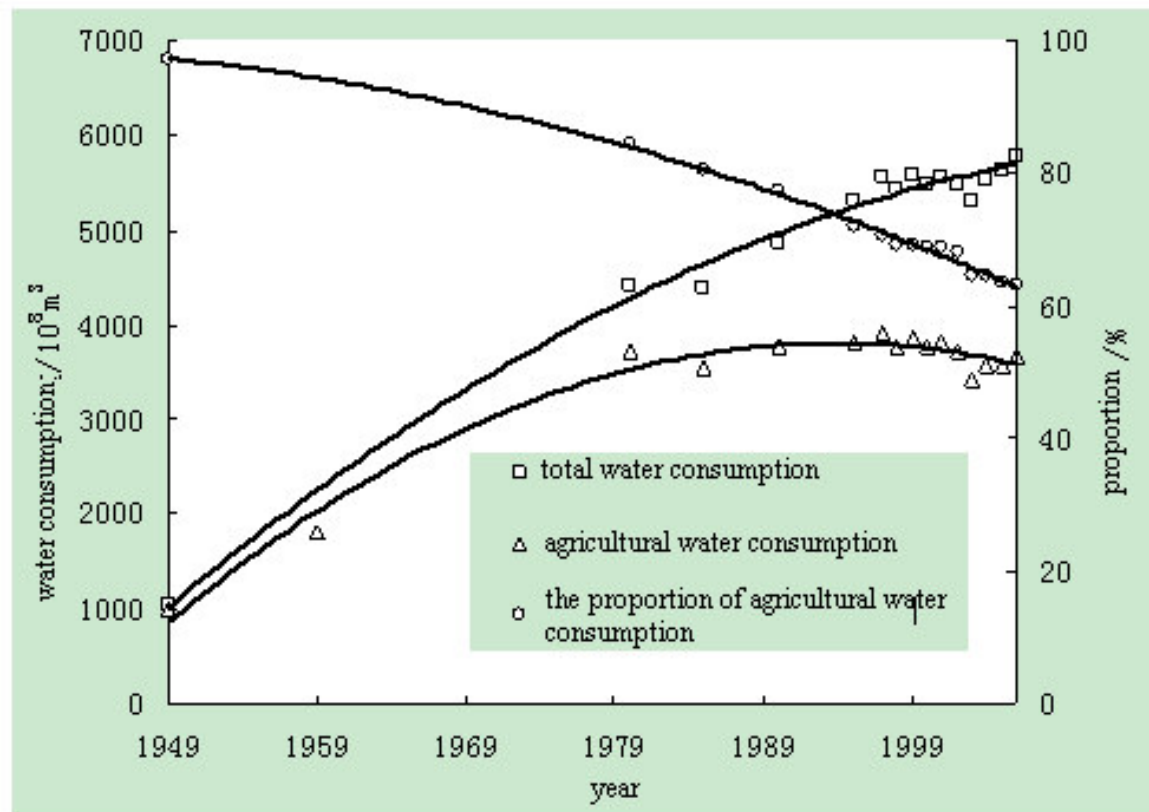


Figure 4. The change of Chinese water using situation over the years.

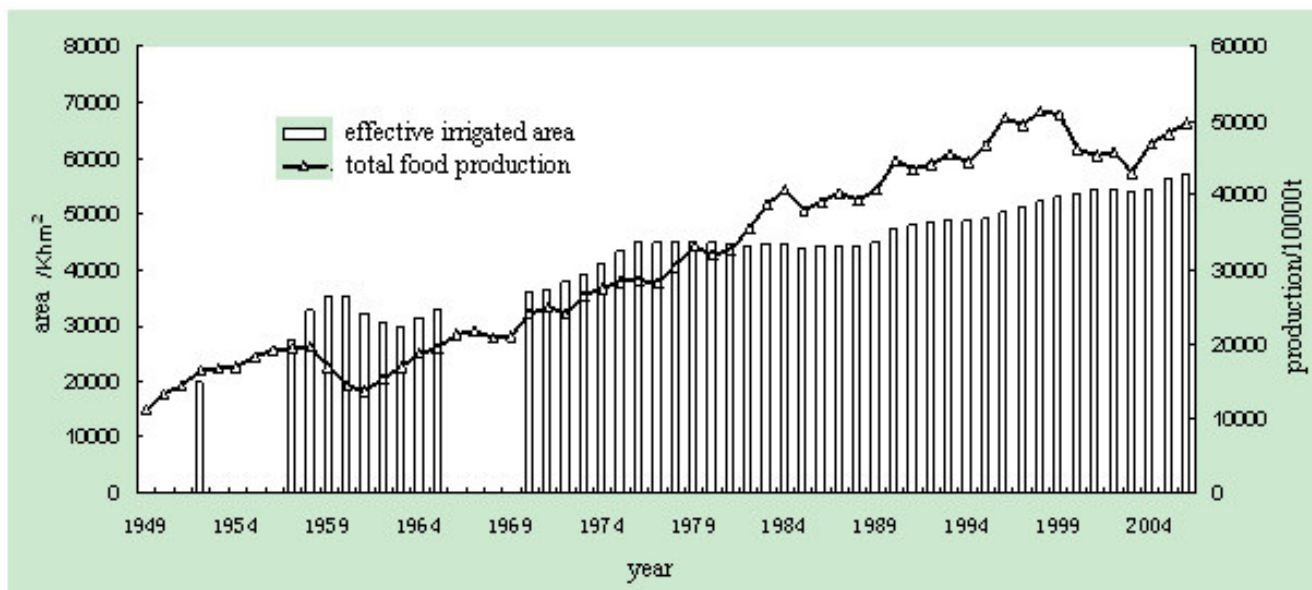


Figure 5. The situation of Chinese effective irrigated area and total food production over the years.

Irrigation plays a leading role in ensuring Chinese food security

As Chinese special natural geographical and climatic conditions, land irrigation plays an important role in agricultural production. From the relationship between the Chinese effective irrigated area over the years and the grain growth (Figure 5), it can be seen that Chinese grain growth is closely related with irrigated area. Considering the factors affecting food production, the growth of irrigation area is a main factor. The change of effective irrigated area also reflects the change of Chinese food production levels to some degree. Under the premise of maintaining Chinese cultivated land with zero or negative increase, effective irrigated area increased from 19959 khm² in 1952 to 57078 khm² in 2006 and food production also increased from 163.91 to 497.36 million t in 2006. The effective irrigated area accounted for 54.2% of the total national cultivated area (National Statistics Bureau Rural Social and Economic Investigation Division, 2006a,b). According to different statistic materials (Gao, 2006), total effective irrigated area reached 57078 khm². Until 2006, there are up to 5860 pieces of irrigation area that spread over 10 thousand Mu with effective irrigated area of 36419khm² and up to 287 pieces of large irrigation area that spread over 300 thousand Mu with effective irrigated area of 14612 khm².

The national water-saving irrigation area has reached 22426 khm² to include anti-seepage irrigation area of 9594 khm², low-pressure pipe irrigation area of 5264 khm², sprinkler and drip irrigation and micro-irrigation area of 3578 khm², field water-saving surface irrigation and other conservation irrigation of 3990 khm². The length of main, branch and lateral canals of irrigation area over

10 thousand Mu accounts for 27.2% of total canal length and water-saving irrigation area accounts for 37.8% of national effective irrigated area. As a result, the agricultural water efficiency increased to 45%. At the same time, it can be found from the comparison of crops that irrigation played an important role in raising crop production (Table 1). The crop production of irrigated land is significantly higher than that without irrigation and the production is 2-3 times higher. The results are more significant in northwest, distracting the fact that there will be no agriculture without irrigation.

The promotion and application of water-saving technologies have achieved significant benefits in the past 20 years. According to statistics (National Statistics Bureau Rural Social and Economic Investigation Division, 2006c), irrigation water consumption reduced from 358 to 330.5 billion m³ by 27.5 billion m³, during 26 years, from 1980 to 2006, while the national effective irrigated area increased from 44.375 to 57.078 million hectare by a net increase of 12,703 million hectare. Food production increased from 320.56 to 497.36 million tons with a net increase of 176.8 million tons and per capital grain increased from 325 to 378kg (Table 2). It can be found from the above mentioned that the decrement of agricultural water and the increment of irrigated area are mainly due to the promotion and application of water-saving technologies.

During the past 20 years, China supported the gross domestic product (GDP) growth of 10% by water supply speed increment of 1.27%. It produced about 75% of national food and 80% of cash crops by 43.5% national total cultivated area. Also, it produced 24% of the world's food and fed 22% of the world's population by only 9% of the world's land.

Table 1. The comparison analysis of crop production as to whether there is irrigation in different districts of China.

Area	Unirrigated land	Irrigated paddy land		Irrigated dry land	
	Production (Kg/hm ²)	Production (Kg/hm ²)	Growth rate (%)	Production (Kg/hm ²)	Growth rate (%)
Northeast	2235.00	5085.00	127.52	3600.00	61.07
Northwest	1117.50	4695.00	320.13	3052.50	173.15
Huanghuaihai basin	2235.00	7305.00	226.85	6075.00	171.81
The lower yangtze region	2685.00	7695.00	186.59	4777.50	77.93
Southeast	3135.00	7785.00	148.33	7050.00	124.88
Southwest	3075.00	7005.00	127.80	6115.50	98.88

Table 2. The change of Chinese irrigation water, irrigated area and food production.

Year	Irrigation water consumption (10 ⁹ m ³)	Effective irrigated Area (10 ³ hm ²)	Food production (10 ⁴ t)	Per capita grain (kg)
1980	3580	44375	32056	325
2006	3305	57078	49736	378
2005-1980	-275	+12703	+17680	+53

THE FUTURE CHALLENGES: CHINESE AGRICULTURAL WATER CONSUMPTION AND FOOD SAFETY

At the same time of gaining great achievement, Chinese agricultural water consumption and food safety also faced serious challenges, such as growing population leads to the sharp decrement of per capital water resource and increment of food needs. Also, the increment of industrial and urban water consumption intensifies the water shortage for food production, as well as serious contradiction between agricultural water and eco-environment water consumption. Considering the point of view of food and strategic water security, the contradiction for recent and medium China is how to meet the food needs for increased population by using limited agricultural water.

Similarly, considering from the perspective of national water-security strategy, Chinese agricultural water consumption can only maintain a zero or negative growth in the next 30 years. This has been taken as an important goal by the Ministry of Water Resources, that is to say, the Chinese agricultural water consumption can not exceed nor should be less than the status amount. The status' supply capacity in China is about 580 billion m³, of which the agricultural, industrial and domestic water consumption is about 370, 130 and 80 billion m³, respectively. Among agricultural water consumption, about 90% was used for irrigation, that is, about 330 billion m³, which is the upper limit of the study's irrigation water. From the perspective of national food-security strategy, the Chinese total grain production is required to achieve 600 million tons by the year 2020 (Figure 6) (Wu et al., 2006). Chinese grain production was about 497.36 million tons in 2006, while

the historical highest yield was about 512.29 million tons (1998). In like manner, when considering the reality that arable land is decreasing due to economic construction and combining the technological progress factors, a production capacity with 600 million tons of food will be reached by 2020, that is, adding 100 million tons of food based on that of 2006 is needed to increase 100 billion m³ agricultural water.

All these created two reality demands, that is, to meet the national strategic water security, Chinese agricultural water consumption must maintain a zero or negative growth; but to meet the needs of Chinese strategic grain security, there is need to increase about 120 billion m³ agricultural water. The two demands formed a pair of contradiction that is difficult to reconcile. Under the extremely limited water resource in China, the only way to solve the contradiction is to vigorously develop modern high-efficient water-saving agriculture relying on science and technology and take the path of internal resource expansion.

STRATEGIC THOUGHT FOR CHINESE AGRICULTURAL WATER CONSUMPTION AND FOOD SAFETY

How to solve the contradiction between Chinese agricultural water consumption and food production is an objective reality faced by the Chinese government. Also, it is an important issue to ensure sustainable development of Chinese economy. In order to resolve the contradiction, there is a need to prove the general concept from a strategic degree. This paper analyzed the issue from a

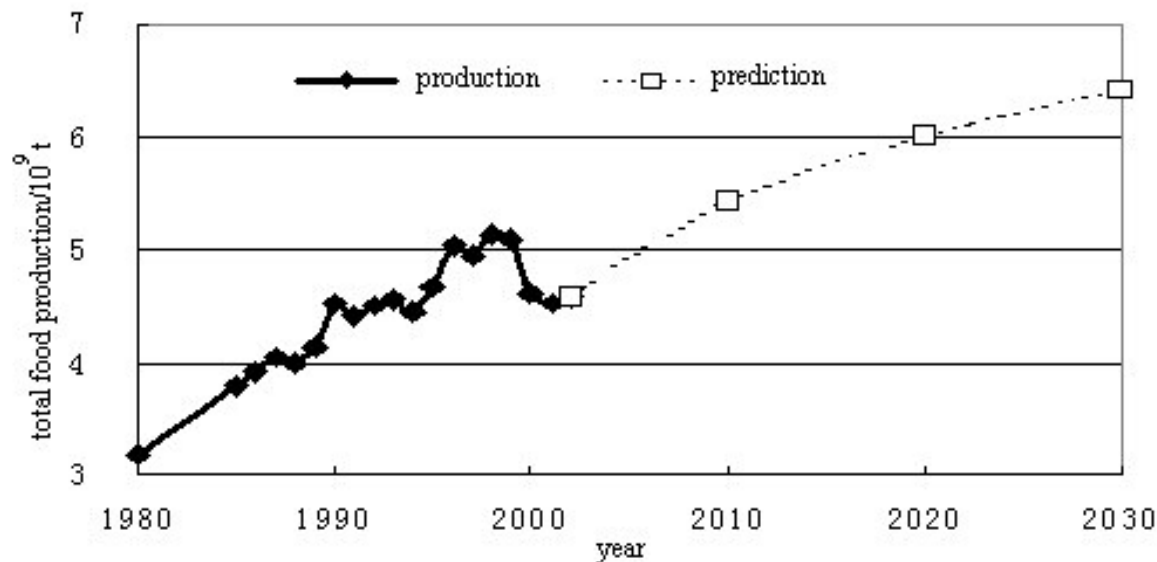


Figure 6. Prediction curve of grain yield of China in past years.

strategic degree and proposed preliminary solutions to the contradiction. From a strategic perspective, it is necessary to focus on strategic technology reserve and also combining source-opening and water-saving. Taking into account the reality that the utilization of irrigation water in China is only about 45%, rainfall utilization is low in dry-land and effective utilization rate is just 30%. The development of Chinese water-saving agriculture should try its best to reduce water waste during water using process on the basis of fully used rainfall water, which vigorously raise irrigation water benefits, reduce irrigation water cost and develop the water-saving potential of agriculture.

The future main regions of Chinese water-saving agriculture is still in the northern regions with serious water shortage, especially the Loess Plateau in northwest and arid fragile ecologically inland regions, the Huang-Huai region, Northeast Plain area, as well as the southern seasonally dry mountainous areas. Water resources are abundant in the southern plains, but the reserve of arable land resources is extremely limited. Even if the water resources are saved, it is also difficult to expand the cultivated area (Wu et al. 2007; Zhang et al., 2009). Accordingly, the following strategic program was put forward.

Raising utilization ratio of limited rainwater from 30 to 45%, saved 45 billion m³ rainwater

There are about 75.010 million hm² out of 130.039 million hm² current cultivated land that are dry-land in China and are located in Chinese semi-arid and dry sub-humid areas. These areas include northeast, northern China and

northwest, which mainly depend on natural rainfall water to supply needs of crops. According to the results of national technology capture, the precipitation utilization of dry-land in the north is not high, but the limited resources were not fully used. Among limited precipitation, the moisture loss due to runoff accounts for 20% of the total precipitation, while the invalid evaporation during leisure period accounted for 24%. Only 56% was used for agricultural production. However, among the 56%, there are 26% wastage due to field evaporation and only 30% of the total precipitation was really used by crops, that is, the average rainwater utilization of dry-land area in China was only about 30%, which is the majority of precipitation wasted as runoff and invalid evaporation (Rural Water Conservancy Division of Water Resources Ministry, 2001). If effective measures are taken in the next 15 years, there will be 15% reduction in evaporative water loss during fallow and growth period through rainwater harvesting project, covering technology, water retaining agent use and increment of soil reservoir storage capacity, that is, the rainwater utilization rate will climb up to 45% and can be raised by 1 percentage point in one year. Calculated by an average precipitation of 400 mm, 11 million Mu dry-land in China can use 60 mm more than ever, which will amount to 45 billion m³. This means adding 45 billion m³ of new water resources for agriculture.

Raising irrigation utilization ratio from 45 to 60%, saved 54 billion m³ water

The average utilization rate of irrigation water is about 0.45 in China, according to current irrigation water status of 330.5 billion m³. Practical and effective water is about

148.7 billion m³, and this is low. During the eleventh-five-year, China plans to increase water-saving irrigated area of 150 million Mu with a net effective irrigated area increment of 30 million Mu and raise effective water using coefficient from 0.45 to 0.5. If irrigation water utilization rate is increased by 1 percent annually, through technology development and engineering demonstration of water-saving irrigation in the next 15 years, in the north west inland irrigation area (where there is no agriculture without irrigation), Ningxia-inner mongalia Yellow River irrigation area, northeast plain irrigation area, HuangHuaihai plain irrigation area and Fenwei irrigation area, the study's utilization rate of irrigation water would reach 0.6 by 2020. By this way, 54 billion m³ water can be saved, that is, agricultural water would increase by 54 billion m³. From the developed situation of national water-saving irrigation, the study's water-saving irrigation development has received greater results through the "Ninth Five-Year Plan" and "Tenth Five-Year Plan" technology capture. It has also received results through the constructions of 300 water-saving demonstrations, as well as the implementation of series projects for the transformed construction of large-scale irrigation area, commodity grain base counties and so on.

The irrigation water utilization has increased from around 0.4 in latter "Ninth Five-Year" to the status level of 0.45, about 1 percent point increment by a year (Liu, 2000; Gong et al. 2003). At the same time, as illustrated from the distribution curve of grain yield and effective irrigation area of past years in China, it can be found that without no-increment of effective irrigation area, the grain output still maintains a certain growth rate during 1980 to 2000. This showed that total grain yield can still be increased without increasing effective irrigation area by using water-saving irrigation technologies (Qian et al., 2002; Shan et al., 2004). In addition, a large number of foreign practices have been proven (for example, the utilization of Israel's agricultural water is 0.75 or more) to be a feasible way to increase agricultural water utilization and save a large amount of water through the water-saving irrigation.

Develop inferior water resource and increase agriculture water resource by 30 billion m³

The current annual sewage discharge is up to 63.1 billion m³ (not including DC cooling water of electric power plant) in China, among which industrial wastewater accounts for 61.5% and domestic sewage accounts for 38.5%. Discharged sewage water mainly concentrates in large and medium-sized cities and industrial areas. However, the current treatment rate for urban sewage was only 43.6%, far from 80 - 90% of European countries and 95% of Israel, and the treated sewage was not rationally utilized. If 60% of the domestic sewage is only used for irrigation, there is still about 14 billion m³ of new agriculture water resources that needs to be added. In addition, there is a great number of brackish water (2 ~ 5

g/L) off northern coastal areas and north-west inland areas in China. Experimental data shows that (Jiang et al., 2005; Zhao et al., 2009), if brackish water mixing with freshwater is reasonably used, crop yield will not be reduced and to some extent the quality of crops will be improved. So, it has an important role in promoting the agriculture development of water-deficiency area to further develop this part and increase its utilization. The available brackish water in China is about 20 billion m³, if the utilization rate increased from 20 to 50% and the agricultural water gain an addition of 6 billion m³. Coupled with 14 billion m³ of available domestic sewage, the goal of adding new agricultural water with 20 billion m³ can be achieved through the development of inferior water resources.

Vigorously raised crop water use efficiency through agricultural comprehensive technology measures

The Chinese crop water use efficiency of current grain production is 1.0 kg/m³ on average (namely, the water consumption for producing 1 ton of grain reaches 1000m³), while the water use efficiency in the countries with developed water-saving agriculture has reached 2.0 kg/m³ (namely, the water consumption for producing 1 ton of grain has decreased below 500m³). Compared to developed countries, there is a great gap in water use efficiency for current Chinese grain production. At the same time, a great potential was reserved. Early research and practice on dryland agriculture and water-saving agricultural technology demonstrate that (Wu, 2005; Liao et al., 2002), under the same conditions as field water supply, there is a gap of 30% between supposed crop yields and real yields, that is, 30% of water use efficiency is lost; this can be avoided through application of water-saving agricultural techniques. To predict based on this experimental result, as long as comprehensive water-saving technologies were used and the potentials of inputs were fully played, a grain production of 650 million tons can be made even under constant water and material supply. Secondly, the water consumption of unit production can be significantly reduced (mainly to reduce the consumption of invalid evaporation) through the agricultural and bio-technology comprehensive measures and crop water use efficiency can reach more than 1.5 kg/m³. If Chinese agricultural water use efficiency reached 1.5 kg/m³, it can produce 600 million tons of grain with current irrigation water amount and the water-saving potential would be obvious.

According to the above strategic program, under the same distribution of total water resources, 119 billion m³ new agriculture water can be added to meet the needs of future additional 100 billion m³ of food production through high-utilization of rainfall water technology, field water-saving irrigation technology and inferior water (sewage, inferior water) utilization technology, as well as technology integration and comprehensive application. At the

same time, it vigorously raised the field crop water efficiency and can produce 600 million ton of grain to realize strategic goal of food production safety.

RESEARCH EMPHASIS

(Wu and Feng, 2003; Wu and Feng, 2005; Sci-Technology Ministry Rural Sci-Technology Department and China Rural Technology Develop Centre, 2006; Water Resources Ministry Rural Water Division and China Irrigation and Drainage Sci-Technology Develop Centre, 2006; Wu, 2007; Zhao et al., 2009),

Biology water-saving technologies

Here, the study focuses on main crops and grass to carry out identification and evaluation on fields or indoor drought-resistance of germplasm resources. It selects outstanding water-saving and drought-resistant resources and establishes evaluating index system and methods for crops' water-saving and drought-resistance identification. Also, it focuses on establishing simple and effective drought-resistant and water-saving germplasm improvement and breeding techniques by using molecular marker-assisted selection and transgenic and gene polymer technology.

New materials are created with drought-resistant, water-saving and high-efficient water-using and new varieties of drought-resistant and water-saving are bred. It creates an exogenous substance that can control transpiration and study crops' eco-physiological response to exogenous substances and the compound technology between exogenous substances and nutrient. To study plant transpiration inhibitor using integrated application of chemical synthesis and sequestration technologies, there is need to develop a multifunctional seed coating agent with drought-resistance and water-saving. This prevents pesticides and enhances environmental protection and high-efficiency for dry-land and deficit irrigation. It studies the deficit irrigation mode under limited water and water production function of the main crop in different regions. Also, it studies the main indicators systems and irrigation model of regulated deficit irrigation, as well as local water controlling irrigation techniques and methods of the main crops.

High-efficient and safe using technology of inferior water resource

Focus is on the research and development (R and D) of new high-efficient engineering, biology rainwater harvesting form and new harvesting materials with low-cost, high-efficiency and environment-friendly that adjusts the dry-land. Study on the structure of new harvesting facilities and on-site molding technology put forward

system design engineering software for rainwater harvesting and high-efficiency utilization. Harvesting establishes a regional rainwater utilization technology system with optimum development model and intelligent decision-making system software.

Study on the effects of reclaimed water irrigation for soil, groundwater and quality of crops put forward the indicators system for safety irrigation and establish an irrigation system under different reclaimed water irrigating patterns by using different irrigation methods. Technologies were then applied for mixed or rotation irrigation of reclaimed water. A study was carried out on the utilization technology and equipment of brackish water with low-cost, energy-efficiency and controlling indicators systems. Crop irrigation systems, as well as salt moving laws and regulation technology under brackish water irrigation, and patterns of mixed or rotation irrigation put forward a set of brackish water utilization that could improve the regional ecological environment.

Technologies and equipment of water-saving irrigation

The study made a research on the technology of soil precise-flat standard and laser controlled leveling and it develops the China-made equipment of smoothing ground and carry-scraper by the control of laser and the corresponding control of the hydraulic lift system. It studies the matching field irrigation and drainage engineering system model and also studies the research surface irrigation techniques that are used to control parameters. It develops both the field surge irrigation control equipment and the field porous gate-pipe irrigation systems and automatic control equipment. The study researches on alternate partial root zone irrigation technology elements and the corresponding field equipment. Similarly, it establishes the technical system of the moisture-retaining irrigation. It structures the digital design and quick shaping platform of spray and micro-irrigation products and manufactures the special energy-saving sprinkler nozzle and light sprinkling of small mobile units with low-pressure pipe for a new type of sprinkler irrigation systems unit. It develops the micro-pressure drip irrigation with ultrathin wall, anti-blocking, durable, low-cost micro-irrigation emitter, automatic backwash filters, precision fertilizer injection device, pressure regulator, precision micro-irrigation control valves and automatic control systems. The study uses nanotechnology to improve the performance of impermeable material and develops new composite materials and fillers geomembrane material.

An expansive study was done on saline soil and other special soil type channels with impermeable material and application-specific technologies. The new developed type of thermal insulation composite material and environment-friendly composite, reinforced concrete and new materials that were used in developing the large-diameter pipe, the pipe fittings, the corollary equipment

for piping water and the polymer composite used. The study exploited the standardization and serialization of the new type of metal pipe and pipe fittings, as well as develops the reinforced high-density polyethylene (PE) moving sprinkler pipe and fittings.

High-efficient water using technology and new material for dry-land

Here, the basic relationship model between water demands and water resource protection of major crops will be established and the main regional water-saving and production-stable crops planting structures will be put forward. Appropriate rain planting parameters in co-ordination with water resource will be established and water-saving, efficient intercropping and rotation cropping patterns will be put forward. The study also puts forward no or less tillage moisture conservation technology and optimal and design software for regional water-saving farming systems, which are adapting to the regional characteristics. Studies will be done on the structure and main components performance parameters of walking multi-function drought-resistant planter, the moisture conservation farming machinery and equipment based on the principle of mechanical bionics and the micro-machines for water lifting and local water irrigation systems that suit small water resource. The study will develop a whole biodegradable plastic using natural and modified materials (focus on plant fiber and starch), research the film forming technology and related equipment for field biological material, exploit multi-function liquid covered material with temperature increments, moisture production, production-increments, no residual, modify and create the new liquid film.

Comprehensive technologies for regional high-efficient water-saving agriculture

Research should be done on regional crop water signal monitoring technology and diagnosis indicator system, as well as rapid determination and forecasting techniques of soil moisture. The study should research on the technologies of dynamic management information collection, transmission and analysis of irrigation area, computer identification for irrigation system, simulation of irrigation water distribution and real-time control of water flow based on network technology combined with 3S technology. Research should be done on the water resources optimal distribution and management model under joint use of multiple water resources. Also, support systems (for regional multi-resources optimal distribution) and intelligent management decision-making should be researched and virtual irrigation realization technology should be explored. The study should select 10 different water-saving agriculture pattern zones and establish about 20 modern water-saving agriculture technology

integrated in demonstration zones. It should assemble technologies of biological water-saving, water-saving irrigation, agronomic water-saving and water management by agricultural high-tech water-saving technology and products application. Modern water-saving agricultural technology systems and models with each feature in demonstration zone needs to be formed. The demonstrative management mechanism and mode should be probed mainly on the farmer's water using association and the diversified investment mechanisms for demonstration zone construction (that are conducive to arouse enthusiasm of scientific research, business, irrigation areas and farmers, etc.) should be explored.

CONCLUSION

- (1) Chinese grain production has basically achieved the historical leaps that transformed from long-term shortage to basic total balance and have extra food in abundant years. However, considering from a long-term point of view, the contradiction for Chinese agricultural water consumption and food production is how to meet the food needs for increased population by using limited agricultural water. The solution to this lies in developing modern water-saving agriculture technology through science and technology, vigorously raising irrigation water benefits and developing the water-saving potential of agriculture.
- (2) With a zero or negative growth in agricultural water, 120 billion m³ of agriculture water can be newly added for realizing food production of 600 million t to ensure Chinese food and strategic water safety through researches and large-area applications of high-utilization of rainfall water, field water-saving irrigation technology and inferior water utilization.
- (3) Modern biological water-saving technology, high-efficient utilization of inferior water resource, water-saving irrigation technology and equipment, dry-land high-efficient technologies and new materials as well as regional comprehensive water-saving technology are research emphasis for water-saving agriculture in China in recent-mid periods.

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