Development of Water Saving Irrigation Technique On Large Paddy Rice Area in Guangxi Region of China

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Abstract

Through 21 years of research and experiment, a kind of non-project water saving irrigation technique for paddy rice has been developed in Guangxi province, China. The mechanism of this technique is to determine the optimal water demands for various growth stages of paddy rice with respect to different areas, soils and climate conditions, summarized as shallow water depth for transplant/recovery phase, being kept wet for pre-tiller phase, field drying for post-tiller phase, again shallow water depth for jointing/flowering/emulsifying phase, and finally being kept wet for yellow maturity phase. The technique saves significant amount of water over the traditional continuous inundation irrigation. It improves the water, fertility, aeration and thermal conditions of the soil and brings tiller into full play, so higher yield is acquired. Such irrigation method gives rise to 21.1% of water saving and 11.4% of yield increase. Based on experiments, this technique was applied for demonstration in 16000ha. area of paddy rice fields in 1990, and expanded to an area of 66,700ha. in 1991, then 82,800ha. in 1992, and finally reached to 950,000ha. which accounts for 40% of the total paddy rice area and approximately 70% of the paddy rice area in 1993. The technique renders tremendous economic, social and environmental benefits. The paper also describes the technical measures and organizational measures for its popularization, of which include the expert demonstration, the pilot demonstration farms for comparison and yield estimate, as well as widespread technical training. It has been demonstrated by facts that such water saving irrigation technique is an effective way out for those water-deficient areas, which deficiency is not due to scant water source.

1 Background

Guangxi region is located in South China, where the annual rainfall varies from 1,300 to 1,500mm. Although water resources are relatively abundant, irrigation water saving for agricultural production is necessary in view of the following reasons.

- The extreme unevenness of rainfall, temporal and spatial. Rainfall is concentrated between April and September from north to south Guangxi, which results in frequent occurrence of aridity in spring and fall, with drought representing more than 60% of the natural disasters.
- Low regulation capacity of water resources facilities, less than 20% of the total water resources quantity.

In Gaungxi water deficiency is not due to scant water source. The countermeasure could be tow-folded, viz. to develop new sources and to reduce the consumption. The development measure included the construction of reservoirs, which incurs the hard nuts of high investment and involuntary resettlement. Therefore there is more scope for water saving. To save large amount of water from agricultural irrigation is a fundamental way out for sufficient water supply to industry, domestic and environmental purposes. In South China, paddy rice is the major crop of agricultural production, and thus the subject of water saving.

Currently structural measures (or we call it facility agriculture) are resorted for water saving both at home and abroad. But in this paper I would prefer to introduce a non-structural measure for water saving, which is realized by enhancing the farmers' technical consciousness, introducing to farmers

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the experimentally proved irrigation technique, transforming the scientific findings into productivity.

2. Contents and Mechanism of Water Saving irrigation

Paddy is the major consumer of water in South China. Traditionally it is irrigated by means of inundation and surface flooding. The traditional method is not scientific and it not only wastes water but also results in low yields. On the other hand, there should be a scientific irrigation program taking into consideration the physiological stages of paddy for water demand, which will not only saves water but also lead to higher productivity. Through long-term observations and experiments on 19 pioneering fields for 21 years, we have worked out the water demands for various growth phases of paddy rice with respect to different areas, soils and climate conditions characterized as "shallowness, wetness and drying". Conceptually the traditional life-long deep water layer irrigation is transformed into different phases corresponding to shallow water depth, zero water depth (being kept wet), and deficit water depth (field drying).

- Transplant/recovery phase: very thin (15~20mm) to shallow (30~40mm) water layer.
- Pre-tiller phase: irrigate every 3~5 days and keep wet under 10mm (zero water layer)
- Post tiller phase: field drying 5~10 days (until field cracking, minus water layer)
- Jointing/flowering/emulsifying phase: reduced water layer from 10~20mm to under 10mm gradually (shallow water layer)
- Yellow maturity phase: zero water layer (kept wet)

—— The technique of "shallowness, wetness and drying" not only result in water saving, but also conforms with the physiological water demand of paddy rice, the essence of which is to rationally control the water supply, oxygen supply to the roots, adjust the ecological environment of the paddy rice and, in one word, improve the water use efficiency, fertilizer, oxygen and thermal conditions necessary for high productivity.

—— The alternative adjustment of "shallowness, wetness and drying" has four advantages. First, the aeration performance of soil is improved, thus sufficient oxygen is supplied. Second, fertility is adjusted and maintained by water, thus the soil environment is refined. Third, the local on-field climate is improved, thus diseases and pests are diminished. Fourth, it is favorable to cultivate vast low productive farmland in South China, which would otherwise remain unproductive due to intense reduced soil conditions(gley soil) because of excessive submergence.

——The alternative adjustment of "shallowness, wetness and drying" matches the tillering of cross-bred paddy rice and the agricultural technical measures such as dry land breeding - sparse planting and factorized seedling breeding.

—— The technique of "shallowness, wetness and drying" provides farmers an opportunity of adopting scientific farming technique and management into practice.

Table1. Paddy Rice Root Development Under Scientific Irrigation and Traditional Irrigation

Rice Type	Irrigation technique	Total roots	White roots	The ratio of the white to the total	Yellow roots	The ratio of the yellow to the total	Black roots	The ratio of the black to the total
Early rice	Scientific	295	95	32.2	185	62.7	15	5.1
	Traditional	275	70	25.5	175	63.6	30	10.9
Late rice	Scientific	276	87	31.8	178	64.2	11.0	4.2
	Traditional	260.7	50	19.2	173	66.3	37.7	14.5

Notes: 1. Scientific irrigation refers to the "shallowness, wetness and drying" irrigation; Traditional irrigation refers to inundated irrigation.
2. White root is life strong; yellow root is life maintained and black root is life faded.

3. Benefits

It has been demonstrated that during four seasons of paddy rice production from 1992 to 1993, the average irrigation water consumption was dropped from 5907m^3/ha to 4659m^3/ha, 21.1% of water being saved. The average yield was raised from 5866kg/ha to 6534kg/ha, with the increase rate of 11.4%. The irrigation water use efficiency was enhanced from 0.99kg/m^3 to 1.4kg/m^3.

Table2. Increased Yields and Water Saving Quantity Under Water Saving Irrigation

Year	Quarter	Area benefited (10^4ha)	Total water saved (10^8m^3)	Average water saved (m^3/ha)	Total increase in yields (10^8kg)	Average increase in yields (kg/ha)
1992	2	82.88 ed(1243.28*10^4)	11.09	1338	3.15	379.5
1993	2	95.29 (1429.38* 10^4)	14.22	1492.5	3.57	375.15
1994	2	100.00 (1500.00* 10^4)	6.80	680.7	2.10	210.00
1995	2	104.84 (1572.64* 10^4)	14.62	1394.4	3.82	360.00

Note: 1. In 1994 Guangxi region had suffered from unusual flooding and waterlogging disaster, which had a serious influence on the scientific irrigation of early rice. Two third of the expanded irrigation area couldn't be measured accurately. It worked normally on the late rice.

2. No accurate statistics of total direct economic benefit was given because of the low rice price and agriculture structure adjustment after 1996 even though most rice fields were under the "shallowness, wetness, and drying" irrigation.

3. The figures in the parenthesis for irrigated areas are expressed in Chinese Mu.

Other extended benefits, both social and ecological ones, were also outstanding.

- Management discipline was changed for better, water disputes were minimized, which contributed to the social stability.
- Substantial saving in fuel and power consumption to combat drought situation.
- The saved water can be used for winter crop production, thus increasing farmers' income.
- Scientific management is promoted, which enhances the technical ability of the farmers and grass-root level water management staff.
- The local small hydro power generation is increased, and domestic water supply facilities are developed, which endows the water management sectors with considerable economic benefits.
- The consumption of fertilizer and pesticide is reduced, which is favorable for the farmland environment protection.

Table 3. Details of the Reservoir Storages in the Similar Rainfall Years Prior and After Scientific Irrigation

Year	Annual rainfall (mm)	The effective reservoir storage (10^9m^3)			
		Early January	Late July	Late October	Late December
1992(scientific)	1381	2.53	6.35	2.53	2.17
1989(similar)	1162	3.33	3.15	1.14	1.09
Difference	219	-0.8	3.20	1.39	1.08
1993(scientific)	1709	2.17	6.30	5.30	4.17
1983(similar)	1730	5.46	4.36	3.36	3.16
Difference	-21	-3.29	1.94	1.94	1.01

Note: the annual rainfalls in 1992 and 1993 were almost the same as in 1989 and 1983 respectively. The increased storage in the respective months demonstrate the significant benefits from the scientific irrigation.

4. Popularization of the Technique among the Farmers

The essence of popularizing water saving irrigation is to change the long-run traditional method of inundation irrigation. In China, the farmers had stood on relatively low developmental level, agricultural production had remained stagnant year after year.. The farmers had been satisfied with simple peace, with no courage to take risk. The farmers were requested to change the traditional habits. The farmers were requested to accept technique and management and implement by themselves. If the implementation comes to a failure, yields will be reduced and the farmers' livelihood in the same year will be directly affected. Therefore the difficulty was imaginable. To deal with this, sufficient preparedness was made, on technique and organization. Prudence can never be overemphasized in practice.

4.1 Technical Measures

Through long-term observation and experimentation, the optimal growth stages and minimum water depth demands with respect to various growth stages of the paddy rice, have been abstracted into an operational rule characterized by shallowness, wetness and drying.

Feasibility study was conducted by the experts from Guangxi Agricultural University, Agricultural Department, Paddy Rice Research Office of Agricultural Institute, Water Resources University and Meteorological Bureau, with appraisal method being inferred.

The popularized area was expanded from 16,000 ha to 70,000 ha further to 950,000 ha. The farmers witnessed the course of popularization and were convinced of the fruitful outcome. About 182 demonstration plots for comparison and yield estimate, and 1,448 pilot fields covering Guangxi region, with the view of letting the facts speak were established. Normally one s[3]pot for comparison and yield estimate is selected from every 6~7 ha of paddy rice field, with the requirements as follows:

- representative physical and chemical characteristics;
- relatively uniform distribution of paddy fields;
- availability of water supply;
- superior accessibility for the sake of visiting.

Table 4. The Average Water Consumption and Yields in 182 Observation Fields between Scientific and Traditionally Irrigated Fields in Guangxi region

Irrigation technique	Year	Type of Rice	Water consumption (M 3/ha)	Yields (Kg)	Productivity (kg/m^3)
Scientific Irrigation	1992	Average	4722.00	6552.00	1.39
		Early rice	4569.00	6832.50	1.50
		Late rice	4875.00	6271.50	1.29
	1993	Average	4597.50	6516.00	142
		Early rice	4521.00	6895.50	1.53
		Late rice	4674.00	6136.50	1.31
	The average in four quarters in 2 years		4659.75	6534.00	1.40
Traditional Irrigation	1992	Average	5953.50	5916.00	0.99
		Early rice	5850.00	6181.50	1.06
		Late rice	6057.00	5650.50	0.93
	1993	Average	5860.50	5815.50	0.99
		Early rice	5896.50	6132.00	1.04
		Late rice	5824.50	5499.00	0.94
	The average in four quarters in 2 years		5907.00	5865.75	0.99

The area of each field for comparison and yield estimate was approx. 600~800m^2, which was divided into two equal pieces with a ridge covered with plastic membrane to prevent seepage. One of the pieces was irrigated traditionally with deep water layer inundation, while the other with the water saving method characterized by shallowness, wetness and drying. Both fields shared exactly the same seedling and fertilization. A specially assigned person was in-charge of the irrigation and drainage from seedling transplantation to harvest, Observation records over the entire period of the experiments were maintained which were checked and accepted by experts from various departments. The fields for comparison and yield estimate become the live teaching material for the farmers.

Propaganda and training were the key factors for popularization. Some 900,000 copies of technical materials were printed and distributed, 14 video tapes were produced, 3,606 s of training classes were conducted, with the number of trainees totaling 286,700. Through the propaganda training, water saving irrigation has become a common term among farmers, its meaning being familiar to everybody. Any visiting mission, both from home and abroad could communicate with a passer-by farmer on the subject of water saving irrigation..

4.2 Organizational Measures

Government action is highly influencing, this is the characteristic of China. Some time the action is a critical agent which determines the success or failure of an undertaking. Multi-department cooperation is a must in the popularization of the irrigation technique over large area. We mobilized all levels of government to perform such cooperation from the fields of water resources, agriculture, meteorology, statistics, university, research institute and technique administration, from which the conscious action of the farmers were developed. We adhered to system engineering approach all the way to establish a popular workable implementation network (see Fig. 1).

It is very important to set up sound grass-root water management teams. Every township has a water station, and every village has a water management group. Full-time water management staff are elected who enjoys prestige among the farmers, have strong sense of responsibility as well as be well educated. They were in -charge of the irrigation management on behalf of all the farmers in the same administrative region, starting from diverting water from the main canals to distributing the water to field in accordance with the technical requirements of "shallowness, wetness and drying". Their remuneration is paid by a special fund of the townships or villages. In the course of popularization, 192,200 water management personnel were posted together with another 53,300 personnel for water facility attendance, an effective water management procession being formed.

At the initial stage of popularization, a county head with an agronomist title normally acted as the leader of the leading group since he has agricultural technical know-how, understands the scientific principle of water saving irrigation, and was sure of the high yield effect. For example, the farmers did not comprehend the draining and field drying at all in the counties of Pingle and Lipu at the initial stage, for the fear that once the subsequent irrigation could not follow in time, the yield would be affected. So they forwarded a request to the county head that if the field drying would cause output reduction, they would demand food compensation from the county government. The county head assured boldly that the county government bear all the consequences which removed the worry of the farmers. The result was, as expected, a bumper harvest, from which the water saving irrigation method won the high recognition of the farmers, and was deeply rooted in the farmers' hearts.

It was also very important to conduct inspection and guide frequently, carry out midcourse appraisal through comparison, as well as encouragement. Farmers will not be convinced of the water saving without high yield. Therefore through out the season of the paddy rice, experts and professionals were called at various levels of government to conduct 2 to 3 inspections, so that any defects can be remedied at the spot and thus assure the success. Numerous midcourse meetings were convened. Over 300 model units and 2,000 model individuals were honored by the provincial Water and Power Department.

5. Conclusions

The measures of popularization of water saving irrigation, with the objective of saving water and increasing output, conform with the situations of China and Guangxi equally. It is a road to developing prolificacy by tapping the internal potential, it is a course of enhancing the scientific and technological perception of the farmers. The decisive agent for the success of the water saving irrigation is the incorporation of technical measures with organizational measures. China is a very populous country, labor forces are available at cheaper cost. The organization of the farmers together with the scientific and technical inputs had definitely given rise to encouraging effects.

Water saving irrigation is a long-way strategic task. Water saving and water resources protection are inevitable for the survival of human beings, they are also the important subject of sustainable development. The rational use of water resources over large area is an effective way out for those water-deficient areas where deficiency is not due to scanty water source.

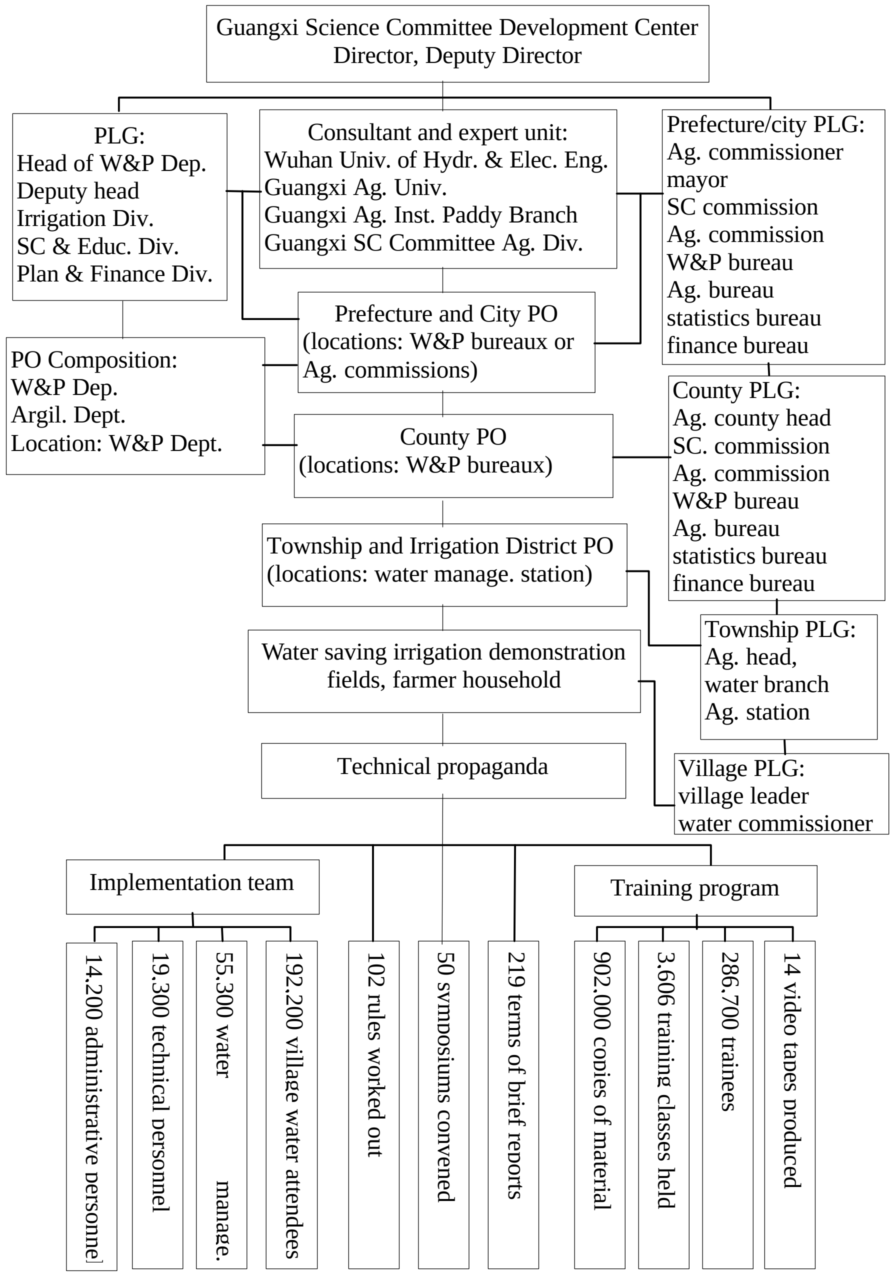

Fig. 1 Organizational Structure

Notes: PO — Project Office, PLG — Project Leading Group
W&P — Water & Power, SC — Science, Ag. — Agricultural