Research on Mode of Ranges Control by Farm and Lateral Ditches

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Abstract: it is abundant in water resource in Heilongjiang province and the level of agricultural mechanization is high, but the disasters such as flood, waterlogging, alkalization and drought are more serious too, at present, the waterlogging in the Sanjiang plain and alkalization in the Songnen plain are the most serious. Because the project quantity of salinization control is large and a lot of investment is needed, the salinization control has not been put the agenda of controlling plan. If the ranges control by farm, lateral ditches is combined with the present project and the operation of modern family farms, the leap development of salinization and waterlogging control can be realized, the new innovation of bringing water conservancy technology into house. At present, two ranges-controlling demonstration areas have been constructed. [Nature and Science. 2005;3(1):49-58].

Keywords: waterlogged disaster; salinization; mechanization; family farm; rainfall drainage and storage for irrigation; ecological water conservancy; bringing science and technique into house

1 Environmental features of water resource in Heilongjiang province

①Heilongjiang province is situated in northeast china and is one of the most important granary areas of China. there are two larger plains — Sanjiang and Songnen plain in Heilongjiang, the former lies in the center and the latter lies in the west, both of the two plains are main agricultural areas of Heilongjiang. Heilongjiang lies in the humid and sub humid mesothermal climate zone and is slightly abundant in water resource. In Heilongjiang, the average annual precipitation ranges from 400 mm to 700 mm, while the water demand of dry farming agriculture is only about 450 mm, the relationship between water supply and demand is balanced, which is the greatest predominance for agricultural development of Heilongjiang. However, because the inter-year and inner-year distribution of rainfall is not uniform in time and space, again influenced by topographical feature, land form, soil, geological structure and other meteorological and hydrological factors, disasters such as flood, waterlogging, waterlogged, drought, alkalization often take place. According to statistics data, the drought and waterlogging disasters account for 55% of all kinds of disasters in the world, among which water disasters (flood, waterlogging, waterlogged, salinization) account for 40% and drought disasters account for 15%, the ratios mentioned above are in accord with those of Heilongjiang. From above, we can see that the flood disaster is more serious than the drought disaster, especially in area where rainfall is above 500 mm. So, the drainage should be attached extra importance to.

②In the Sanjiang plain, the largest daily rainfall that can reach 60mm only takes place once every five years, the largest daily rainfall that can reach 90 mm only takes place once every ten years, and the runoff yield is only about 20 mm and 30 mm separately under good draining conditions. Compared with the domestic standards that regard the daily rainfall reaching 100 mm as light waterlogging, daily rainfall reaching 150 mm as medium waterlogging and the daily rainfall reaching 200 mm as heavy waterlogging. The damage degree caused by waterlogging disasters that take place once every five to ten years in the Sanjiang plain is even below that of the light disaster. The Sanjiang plain is an area of little or hard runoff yield under saturated storage. In the Sanjiang and Songnen plain, because of the flat surface relief, the sophisticated micro relief, the high organic-bearing soil and the freezing and thawing phenomenon, it is easy to form plenty of surface residual water and perched water, which will make soil excessively humid and finally cause waterlogging and saline-alkali disaster. The flood and waterlogging is relatively lighter

than the waterlogged and alkalization in the Sanjiang and Songnen plain. At present, control of waterlogged and alkalization has not been attached much importance to and has not been put on the controlling agenda of Heilongjiang. This is the second feature.

Not only does the excessive moisture of soil influence the growth of crop, but also it can make dryland crop die from suffocation. The high soil viscosity and the formation of soil cold slurry decreases the soil bearing capacity and cause great influence on the management of tillage, especially on the large-scale mechanized tillage of modern agriculture. All of above will cause zero yield locally and yield reduction globally and will finally form vicious circle of agricultural operation loss. Salinization can make slick spot of green farmland and is the main cause of land desertisation in Heilongjiang. This is the third feature.

Because it is abundant in water resource in Heilongjiang province and the relationship between water supplies and demands is balanced, so, the drainage should be combined with storage and irrigation to make reasonable use of water resource such as return water, runoff and so on in control. This is the fourth feature.

Table 1. Water supply and demand in Sanjiang and Songnen plain

Area	Songnen plain	Sanjiang plain
Climate	Sub humid mesothermal climate zone	Humid mesothermal climate zone
Quantity of precipitation (mm)	400-700	500-600
Farmland density (mu/km^2)	464	325
Residential density (people/km^2)	130	46
Value of industrial output (RMB/km^2)	90000	20000
Water supply (m^3/km^2)	50000	55000
Average water supply (m^3/people)	400	722
Modulus of water demand (m^3/km^2)	50000	30000
Average water demand (m^3/people)	300-600	600
Evaluation	Balance between supply and demand	Surplus of supply

2 Difficulties in waterlogging and salinization control

At present, only controlling measures such as the flood and waterlogging drainage, drought-resistance irrigation and so on have been taken in Heilongjiang, while the control of waterlogged and salinization which are the main contradictions and disasters has not been put on the agenda. By analyzing the reason, the problem of subjective cognizance is the main reason, there also exists an important objective reason that the control of waterlogged and salinization disaster is hard to be done and need a lot of investment.

① The drainage modulus is too large. In Heilongjiang, the surface residual water and groundwater with excessively high level (including perched water) cannot be drained horizontally and the upright drainage such as evaporation is the only way that can be depended on, which will cause the excessive moisture of soil and surface salt accumulation. Because the surface is not flat, the residual water can reach 30~50 mm (including paddy field with flat land accuracy ± 35 cm), plus the gravity water, the quantity of water is larger. Through analyzing data of the subsurface drainage test that was made in Baoqing county in the Sanjiang plain in 1981, we can find that the largest drainage modulus can reach above 60 mmd (Table 2, Figure 1), which is equal to the largest drainage modulus 60 mm ($q_{max} \approx 3R$) that can be formed by 20 mm runoff caused by the largest daily rainfall that happens once every five years. From Figure 1 and Figure 2, we can see that the subsurface drainage degree is large and the time of drainage is long, the changing rate of surface drainage degree is small and the drainage time is short (normally less than one day), the drainage process is under the control of subsurface drainage, the drainage process has the features that the obvious

controlling stages of surface, subsurface and evapotranspiration drainage are formed (Figure 2.), which is different from that of abroad and domestic areas with plenty of rainfall. The modulus is six times as large as the average one that is about 10 mmd (0.124 $m^3/s.km^2$) and formed under condition that one-day's rainfall can be drained in two days.

Table 2. . Degree of groundwater drainage (1981, Baoqing Farm of Heilongjiang province)

Time 6/month	28/9	29/9	30/9	1/10	2/10	Demo
Average modulus of drainage /mm • d^{-1}	41.26	15.64	11.42	10.40	9.93	Embedded depth of concealed gutter1.0 m, interval 10 m

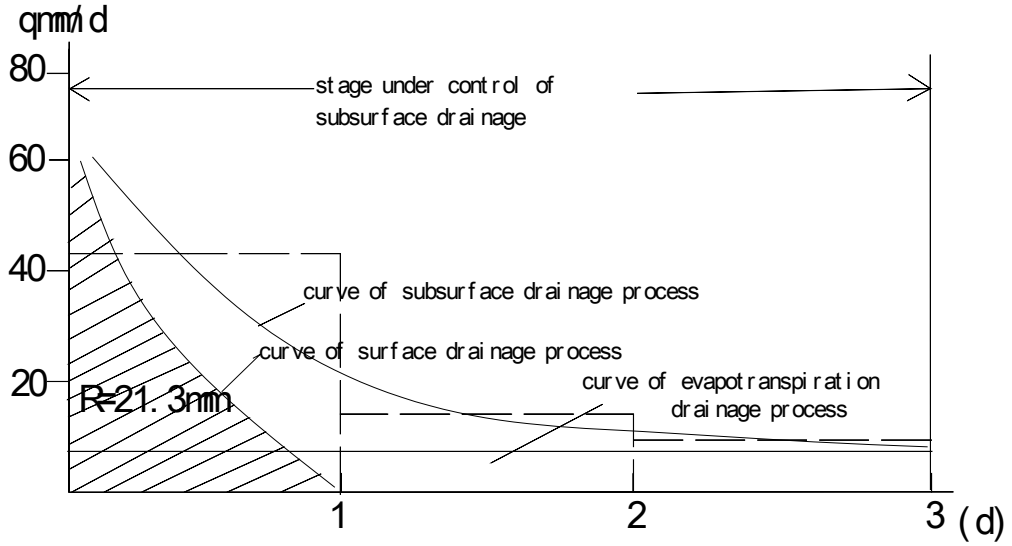

Figure 1. Diagram of surface and subsurface drainage degree in Sanjiang plain

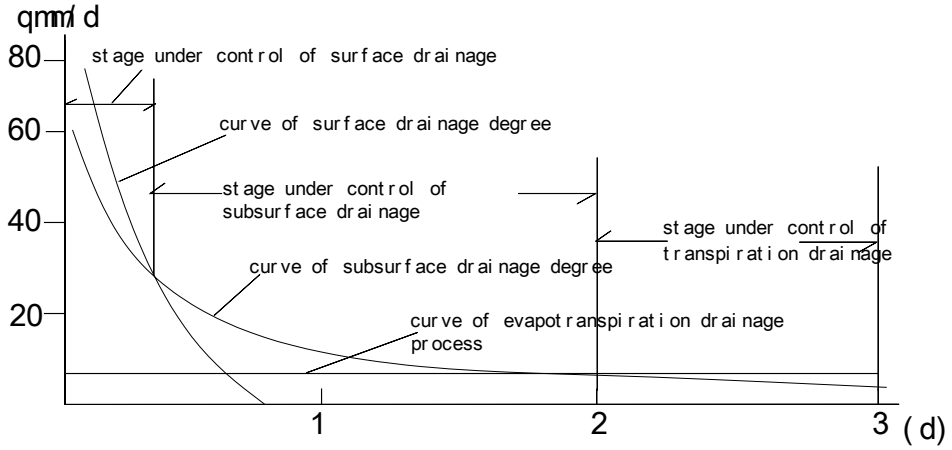

Figure 2. Diagram of standard drainage degree in area with plenty of rainfall

② The designed water level should be lower. Generally, the reference water level of drainage in waterlogged and salinization control should be the lowest surface elevation, and the groundwater embedded depth in waterlogged control should be 0.8~1.0 m deep below land surface and the groundwater embedded depth of salinization control should be 1.2~1.5 deep below land surface. Only thus, can thedemand of mechanized operation and controlling salinization drainage be met. however, the reference water level in farm ditch design is 80%~90% of surface elevation in the past, the designed water level is equal to or 0.2~0.3 m less than the demand. So, the designed water level should be much lower than that in the past in order to meet the demand of mechanized operation and salinization control.

③The ditches of draining system are deep and the project quantity is too large. By adopting the largest modulus of 60mmd and area factors in the cross-section design of farm, lateral and branch ditches (Table 3.), we can get the depth of farm ditch should be 1.5~2.0 m, lateral 2.0~2.5 m, branch 3.0~3.5 m (Table 4.). So, the main ditch should be deeper and project quantity is usually very large, the project is hard to be carried out. The authors had ever carried out ranges control by branch ditches in Dongxie general drainage system of 4^{th} branch of Friendship Farm. Sluice stations were built at the branch ditches exit to force drainage, the water flow into Dongxie main ditches (the compound cross-section that flood can pass on the surface is adopted in the design of Dongxie main ditch).

Table 3. Factors of area used for discharge calculation of drainage ditch (reference to manual of USA)

Area /hm^2	20	50	100	200	500	2000	4000
C	1	0.86	0.75	0.64	0.5	0.4	0.38

Table 4. Longitudinal and cross section Design of farm, tributary and lateral ditch

Ditch	Control area /hm^2	Discharge /m^3/s	Slop /i%	Slop factor	Bottom width /m	Designed water depth	Reference ditch depth /m	
							Waterlogged control	Saltern control
Farm ditch	20	0.138	1/2000	1.25	0.8	0.32	1.5	2.0
Lateral ditch	200	0.880	1/4000	1.5	2.5	0.56	2.0	2.51
Branch ditch	2000	5.71	1/5000	2.0	4.0	1.22	3.0	3.5

3 Modes of ranges control

With the advance of science and technology and the development of agricultural economy, in Heilongjiang province, the draining and irrigating power and equipments are kept at large and the family farms are operated prevalently, among which the area of little and middle-scale family farms is 10-20 hm^2 and the area of large-scale family farms is about 100-200 hm^2, which are both the right scales that can be controlled by farm ditches and lateral ditches. Ranges control by farm and lateral ditches can be designed with the waterlogged and alkalization control as main aim (including the high-standard control such as field buried pipe drainage, laser land grading and so on), and the trunk and branch ditches only need slight remaking (the water level of trunk or branch ditches can be above the land surface temporarily if conditions permit), thus, the project quantity and investment can be greatly decreased, which is of great advantage for promotion and application in practice. It is a leap development in drainage standard and controlling stage to stride into high standard waterlogged controlling stage from

low-standard water logging stage. Combined with well irrigation and low-water-level operation, it will form the water conservancy mode of drainage of precipitation and storage for irrigation or water conservancy of water diversion, drainage of precipitation and storage for irrigation, which will form ecological water conservancy consisting of disaster-resistance type, resource type and environment type water conservancy. Because the ranges-controlling scale matches with the scale of family farm, it can be regarded as water conservancy mode of science and technology into house, briefly called water conservancy-into-house mode (Figure 3), the key lies in that the farm ditches and lateral ditches are designed with waterlogged control as main task.

To achieve the combination of drainage and irrigation and good order between precipitation and storage, deep ditches of flat bottom and adverse slope should be designed in ranges, at the exit of which sluice stations should be built. The deep ditches (the inner ditches are deeper than the outer ditches) can be used for waterlogging control during flood period. Besides gravity drainage by keeping the sluice opened, forced drainage by keeping the sluice closed can be made to keep the water level staying below the exit of buried pipe. Diversion can be made by keeping the sluice opened to coordinate with well irrigation. As usual, the sluice can be closed to store water, when the water level should be less than 1 m. Thus, the functions of drainage, precipitation, storage and irrigation are performed. The sluices used for water retaining and diverting are the gates of controlled ranges. By taking farm ditches for examples, ϕ250～300 continuous culvert pipe can be buried, in which the wooden plugs can be used as sluice gate, the ϕ350～300 axial-flow pump of 500～1000 T/h flow rate and 12～15 horsepower can be used in sluice stations, it can be used both for pumping irrigation and tillage. Ditches can be used for irrigating farmland and draining water out of controlled ranges. If area of ranges controlled by farm ditches reaches 20hm^2, it should be under one farmer's control; if area of ranges controlled by lateral ditches reaches 100～200 hm^2, it should be under control of a large-scale family farm. The new ranges-controlling mode will cause leap development in water conservancy science and technology and will become the leading demonstration mode of ecological water conservancy construction in Heilongjiang. Combined with "bringing science and technology into family", it will become a domestic technology innovation of "bringing water conservancy in to family".

4 Ranges-controlling practical examples and its operating feedback information

4-1 Introduction about ranges-controlling examples

Besides ranges-controlling mode adopted by 4th branch of Friendship Farm, there are two more regular ranges-controlling examples in farm-ditch scale, i.e. ranges-controlling demonstration area in 14th group of 850 Farm and ranges-controlling demonstration area of Qingfeng seeds company. The area of the two demonstration areas both is 25 hm^2 or so. The comprehensive controlling measures such as gate, pump, ditch, channel, well, pipe, culvert, joint, land grading, slope making and trench construction are all taken in the two demonstration areas, and the main aim of which is waterlogging control. In the two demonstration areas, the central ditches are all designed to be in connection with hydro projects by adverse grade ditches. Thus, the forced irrigation and forced drainage can be made and the water separation between outer and inner, free water retaining and diversion, combination of drainage and irrigation. Storage is also achieved. Figure 4 and Figure 5 are layouts of two demonstration areas; Table 5 and Table 6 are project quantity and cost of engineering construction and equipment.

4-2 Benefit and operation

①Since the construction of ranges-controlling demonstration area in 14th group of 850 Farm was completed in 1998, it has experienced serious waterlogging disasters in 2000 and 2002 (annual rainfall reached 726 mm and 660 mm separately) and drought disasters in 1998 and 2001 (the annual rainfall reached 441.3mm and 450.2mm separately).But, the yield of dryland and paddy field increased stably. During the period of 1998~2004, on land that could not be tilled in the past, the unit yield of beans ranged from 2250 to 2400 kg/hm^2, the unit yield of rice ranged from 7500~9000 kg/hm^2. especially in 2003, because the market price of beans was high, the net profit of 12hm^2 dryland reached 60 thousand Chinese Yuan, these lands become middle or high-class lands.

Because of the combination of draining and irrigation, the good order between precipitation and storage and the associated use of surface water and groundwater, the comprehensive utilization of local water resource is achieved (Table 7).

②The ranges-controlling demonstration area of Qingfeng seeds company was constructed in 2002, after two year's operation, three everlasting waterlogging and low-lying barren lands died away and three-year continuous waterlogging disasters which had happened during the period of 2002~2004 were conquered. The special area is made of prohibited area for agriculture. The zero-yield land in the past become high-yield land, and the yield increased by more than 15% compared with that on high flat land (table8. table 9). Not only has the diversion, drainage and irrigation been done well, but also the good order between precipitation and storage and the comprehensive utilization of local water resource are achieved. The ecological water conservancy consisting of water conservancies of disaster-resistance type, resource type and environmental type was formed.

4-3 Problems and countermeasures

①Being short of detailed research on waterlogged disaster control, a situation comes into being, in which the design lacks theorization and standardization, the implementation lacks regularization, the measures lack synthesis and some completed projects even lack corollary facilities. This makes the benefit in ranges unstable in time and space. In 2004, the science and technology park was caught by disasters too, the yields on some lands decreased by more than 70%.

②The technique and method of monitoring and construction is not advanced, especially that the laser technology is not used in the survey of spoil leveling, land grading, slope making and trench building and the surveys lack accuracy control and are mostly made by visual observation, which results in a lot of man-made secondary closing low-lying land. During the process of buried pipe construction, sometimes the depth is too large and sometimes the bottom slope is not flat, which combined with lack of control over quality of filler and filter material greatly influences the benefit and effect of project.

③The two ranges-controlling demonstration areas are both separately operated by several different farmers, the operating management is not made much of , the operating contradiction between drainage and irrigation and new argument on water conservancy come into being. The paddy field farmers usually attach much importance to water storage and irrigation, and the dryland farmers usually attach much importance to precipitation and drainage, sometimes, even no adjustment is made. It is hard to perform the general comprehensive ranges-controlling function, sometimes the disorder between precipitation and storage is caused, and the advantages change into disadvantages.

④There also exists phenomenon of making much of irrigation and little of drainage. Generally, the positivity of irrigation is high, but the farmers know little about draining precipitation, especially about the forced drainage. In operation, the forced draining machines are rarely used to drain water during flood period.

New countermeasures should be taken to solve the problems mentioned above.

- enhance research on techniques, standards and measures of controlling waterlogged and salinized fields.
- elaborately carry out the planning and designing of ranges control.
- attach more importance to utilization of high-new practical technology such as using laser for land leveling , buried pipe construction and ditches digging.
- elaborately carry out implementation of systematic project and comprehensive controlling measures and its operation management and updating.
- attach more importance to using small scientific satellite for data collection, survey, monitoring and control.
- adjust operating mechanism to make the scale of ranges control match with the scale of family farm.

Only thus, can we truly achieve the rapid development of hydro science and technology and practice in Heilongjiang province, and we can make this new water conservancy technology used in family farm.

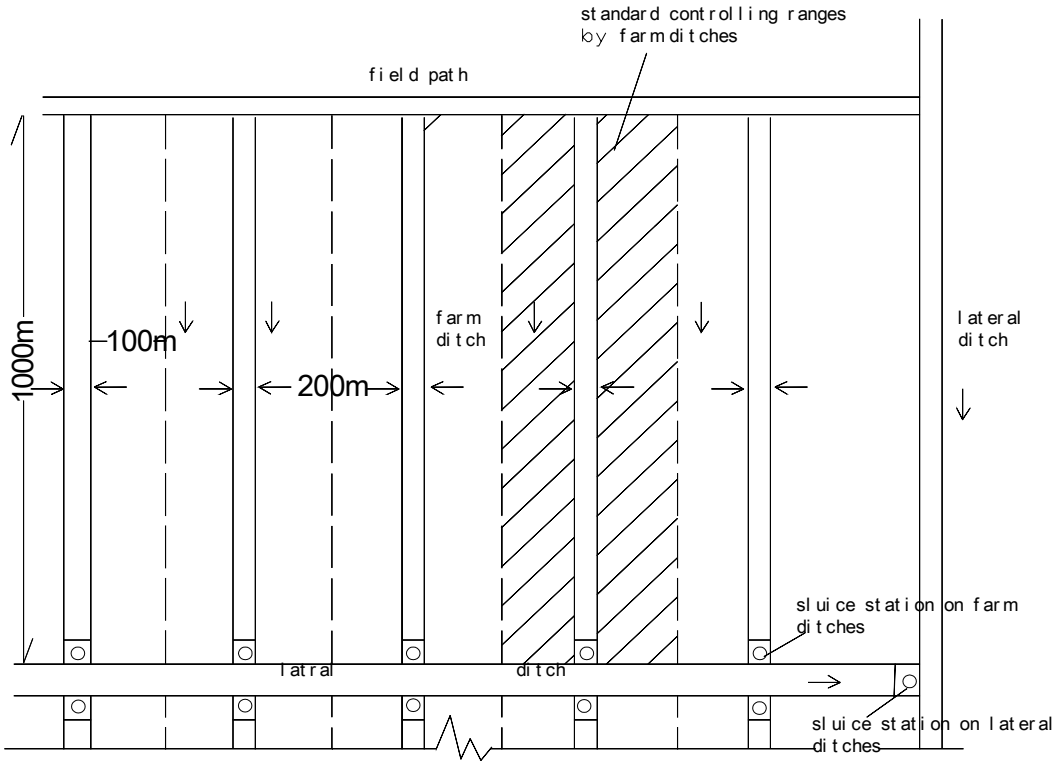

Figure 3. Program of ranges control of farm, tributary and lateral ditches.

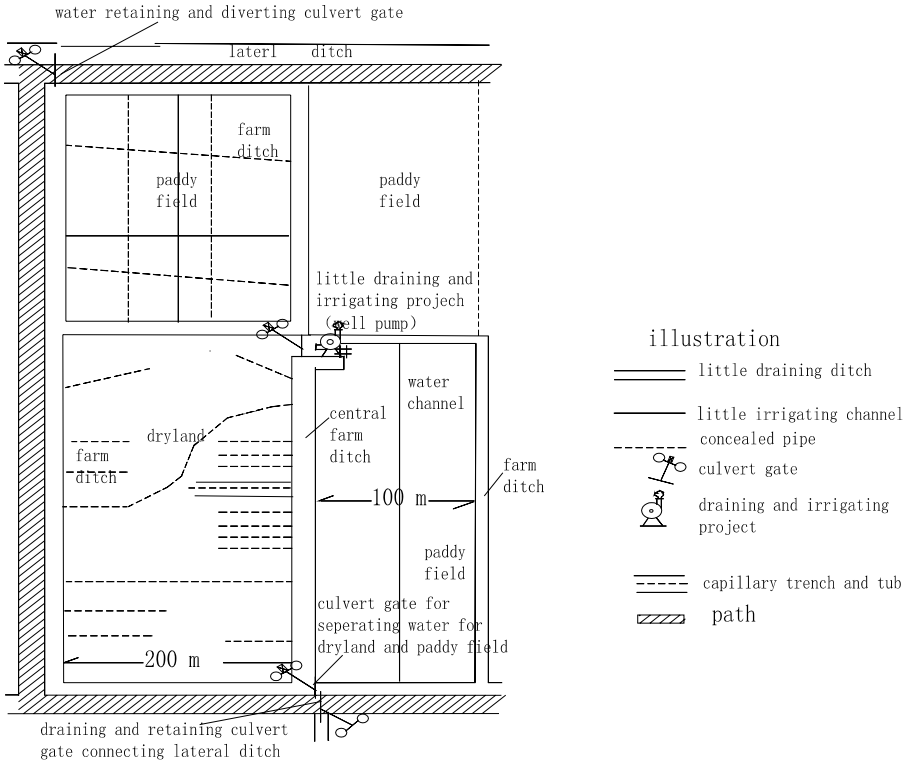

Figure 4. Schematic drawing of ranges control demonstration area in 14th group of 850 Farm

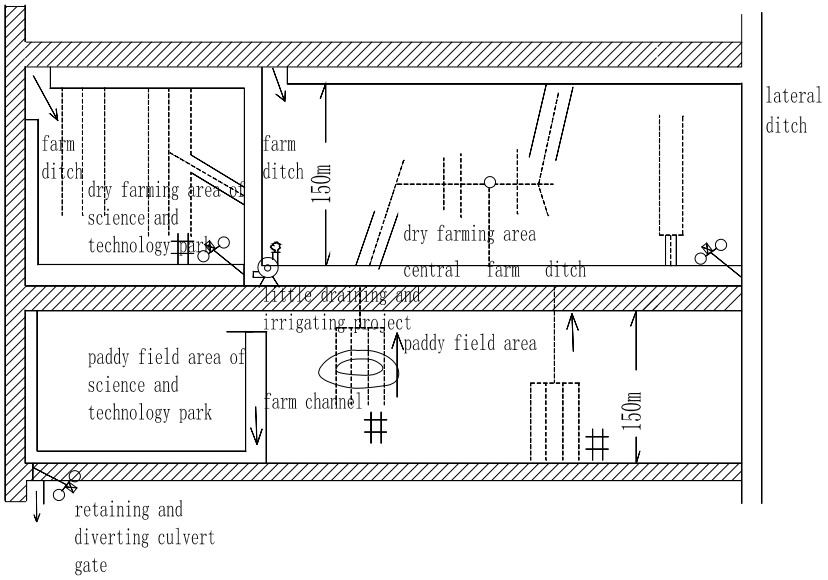

Figure 5. Ranges-controlling schematic drawing of demonstration area of Qingfeng farm's seed company on Sanjiang plain

Table 5. Constructing cost of ranges-controlling project in ecological water conservancy demonstration area in 14th group of 850 Farm

Project	Kind	Volume	Unit cost /RMB	Constructing cost/10^4yuan	Demo
Farm ditch	Earthwork	$1.85\times10^4m^3$	2.0	3.70	
Flat land trench	Earthwork	$0.9\times10^4m^3$	2.0	1.80	Flat Paddy field is not included
Concealed pipe	Dryland	0.15×10^4m	20	3.00	Sand and gravel filler
	Paddy field	0.09×10^4m	20	1.80	
Mole channel	Dryland	12hm2	300	0.36	
Culvert gate	Dryland	4	1000	0.40	
	Paddy field	1	10000	1.00	
Draining and irrigating equipment	Pump	2	0.3×10^4	0.60	
	Well	1	0.3×10^4	0.30	
Total				12.96	26.67 hm^2

Table 6. Constructing cost of ranges-controlling project in ecological water conservancy demonstration area of 14th group of 850 Farm.

Project	Kind	Volume	Unit cost /RMB	Constructing cost/10^4yuan	Demo
Farm ditch	Earthwork	$1.55\times10^4m^3$	2.0	3.1	
Flat land trench	Earthwork	$1.20\times10^4m^3$	2.0	2.4	Flat Paddy field is not included
Concealed pipe	Dryland	0.20×10^4m	15	3.00	Rice crust filler
	Paddy field	0.18×10^4m	15	2.70	
Mole channel	dryland	$12hm^2$	300	0.36	
Culvert gate	Culvert gate	3	1000	0.60	
Draining and irrigating equipment	Culvert Pump	4	0.3×104		
	Well	3	0.3×10^4	0.90	
Total				14.96	Area24hm2

Table7. Surface and groundwater Utilization in ranges-controlling area of 850 Farm

Year	Well water		Ditch water		Gross volume	Irrigating quota (paddy field/$m^3(hm^2)^{-1}$
	Time/h	Uolume/m^3	Time/h	Volume/m^3		
1998	356.3	28500	141	29880	58380	7960
1999	271.5	21720	213	54900	76680	8737
2000	342	27360	443	66450	93750	7800

Table 8. Yield measurement of Qingfeng Seeds Company ranges-controlling demonstration area (Beans, 2004)

Treatment	Plant height /cm	Legumen's amount /plant$(m^2)^{-1}$	Granules /Legumen	Empty rate /%	Unit yield In theory /kg $(hm^2)^{-1}$	Rate /%	Demo
Typical low-lying land	125	28	32.1	84	4236	121	
High flat land	84	27	29.4	72	3501	100	

Table 9. Yield measurement of Qingfeng Seeds Company ranges-controlling demonstration area (Rice, 2004)

Treatment	Plant height /cm	Legumen's amount /plant $(m^2)^{-1}$	Granules /Legumen	Empty rate/%	Unit yield In theory /kg $(hm^2)^{-1}$	Rate /%	Demo
Controlled low-lying land	85	662.58	63.44	6.24	10.25	116.5	
Low-lying land	86.5	520	72.84	10.70	8.79	100	

③Through the preliminary analysis on the two practical examples above, we can get that the average investment is 5546 Yuan/hm^2 and the average benefit is 1208 Yuan/hm^2, the cost can be covered in five years, it is feasible in economy.

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