Submission 75

EFFECTIVELY ADDRESSING GROUNDWATER MANAGEMENT AND RURAL CLIMATE CHANGE IN SHANXI PROVINCE (PRC)

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Abstract

The North China Plains are under close vigilance as groundwater tables are in decline – threatening to undermine one of the world's most important grain baskets. Shanxi Province is no exception to this: in 25.5% of the area groundwater is overused – leading to falling groundwater tables and in some areas land subsidence.

Under the 0188-PRC Grant Climate Change Adaptation through Groundwater Management) demonstration activities were undertaken in four counties to address both groundwater scarcity and climate change. In particular different innovative efficient micro-irrigation systems were introduced in different parts of the Province.

Another important pilot was – implemented outside the scope of the 0188-PRC grant – the introduction of a regulated groundwater system on all wells in the district of Qinxu. This paper describes these pilots and their relevance for groundwater management and climate change adaptation. The micro-irrigation pilots were put in place in 2012 and have one season running behind them, whereas the Qinxu system has been in place for more than five years.

Key words: *Shanxi, groundwater, depletion, regulation, micro-irrigation, climate change, agriculture.*

1. Background: groundwater and climate challenges

The North China Plains are under close vigilance as groundwater tables are in decline – threatening to undermine one of the world's most important grain baskets (Evans et al. 2002; Qiu 2010). The dry northern plains of the People's Republic of China (PRC) produce half of the country's wheat and one-third of its corn. They do so by using groundwater at a rate that largely exceeds the way at which it is replenished. One estimate is that not less than 130 Million people in PRC depend for their staple food on the unsustainable use of groundwater, as the contribution of non-renewable groundwater abstraction for irrigation accounts for $20 km^3 yr^{-1}$ (Wada et al. 2012). The ramifications are enormous: once PRC would run out of groundwater and the country would have to resort to the world market for its grains, food prices would skyrocket all over the globe. PRC's wheat imports have already increased, one factor in the higher grain prices of the last five years. This trend is expected to continue in the coming years (OECD/FAO, 2011)

In the North China plains region, tube well irrigation has helped to maintain a high agricultural and industrial growth rate (Shah et al., 2003).Agriculture in North China is then based on fragile footing. With the development of Shanxi heavy chemicals industry base and agricultural production, water demand became much larger. In 2000, groundwater abstraction in the province was 3.873 billion m^3, accounting for 67.6% of the water supply for the whole province. This new groundwater exploitation trend changed the regional natural flow of groundwater, forming a large area of drawdown cone centers on city water sources and irrigation wells. This has also caused environmental problems such as the aquifer depletion, land subsidence, and spring exhaustion (Evans et al. 2002).

By 2009 there were 103,949 groundwater abstraction points, with 96% of these operational. During the last decades, groundwater extraction has been increasing every year. In 1984, the amount of groundwater resources extracted in the province was 2.483 billion m^3, and this figure went up to 3.873 billion m^3 in 2000. The average annual rate of growth on groundwater abstraction is 3.5 % . The reasons behind this overexploitation have been pointed as lack of co-ordinated planning and management of water resources. In 2005, the overexploited area was estimated to be up to 6903 km^2, accounting for 25.4 % of the whole basin. The overexploited area covers 40 % of the whole basin area in Taiyuan, Jinzhong and Yuncheng. In the cities where groundwater is the major source of drinking water such as Taiyuan, Datong, Jinzhong, Yuci and Jiexiu, land subsidence and fissure have been observed at different levels. But overexploitation is not the only issue. The shallow groundwater in Taiyuan, Datong, Changzhi, Yangquan, Yuncheng, and other regions suffers from different degrees of pollution. In recent years, the large quantities of groundwater being extracted together with sewage discharge, activities of coal mines and the influence of human activities are worsening the groundwater quality. This situation is also aggravated by the natural fluoride and arsenic concentrations in groundwater. It is expected that with the increase of groundwater extraction and the prolonged drinking by local population, the incidence and degree of arsenic poisoning for instance may increase (Source: Appendix 5).

Added to the falling groundwater tables is the decrease in rainfall and the rise in temperature. In Shanxi Province rainfall decline amounted to 99 mm over 50 years, equal to 12%. The decrease is mainly caused by precipitation decline during

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rainy season (June–September), although precipitation in post-rainy season (October - November) also shows a decrease. Decrease in precipitation is highest in central Shanxi and in the area along the west fringe between Sanchuan River and Fenhe River in western Shanxi (Fan and Wang 2011).

At the same time temperatures on average increased with 1.2 degrees Celsius in the same period – while this created new farming opportunities it also stands for higher water consumption. In all seasons air temperatures increased, but winter, spring, and autumn experienced the most pronounced increase in air temperature: for winter the increase was 0.44°C/ 10 year; for spring 0.32°C/10 year and for autumn 0.17°C/ 10 year. No significant trend was detected for summer.

This paper discusses a number of pilot activities – initiated by the 0188-PRC project[2] (Qixian, Xi, Pinghsun, Lishi) and the Provincial Government (in case of Qinxu) to promote efficient use of water in irrigation as well as to manage groundwater (see map and table). The 0188-PRC counties were selected after a careful scrutiny of a long-list of eight relative poor candidate counties of the 26 covered in the ADB-supported *'Comprehensive Development of Agriculture in River Basins of Shanxi Province*' loan project.

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[2] The project was supported by ADB with pilot investments and technical assistance on groundwater management and climate change

In PRC, direct groundwater regulation can more easily be implemented since water-related institutional structures reach out to the farm level (Aarnoudse 2012). The pilot counties were chosen for their representativeness of different areas of Shanxi Province and the interests by local government and farmers and were introduced after considerable discussion with these stakeholders.

County	Village	Pilot system
Qixian	Xiliuzhi	Drip irrigation in greenhouses, including electricity saving frequency converter
Xi	Quyan	Spring (large diameter micro-irrigation) for orchards in loess plateau
Pingshun	Wanli Wangqu Henantan	Micro-sprinkler in mesh tents for prickly ash shoot cultivation
Lishi	Xiaoshentou	Drip/micro sprinkler irrigation in green houses combined with warming ponds
Qinxu	Entire district	Tradeable quota system, tiered pricing, swipe cards, automatic water level recorders, data control centre

This paper first (section 2) discusses the experimental activities in efficient irrigation and groundwater in the lowlands where overuse is most prevalent. The subsequent part of the paper (section 3) concerns the hilly tracts, where overuse is not a problem, but where agricultural expansion to keep up with the increased demand for (high quality) food is best located.

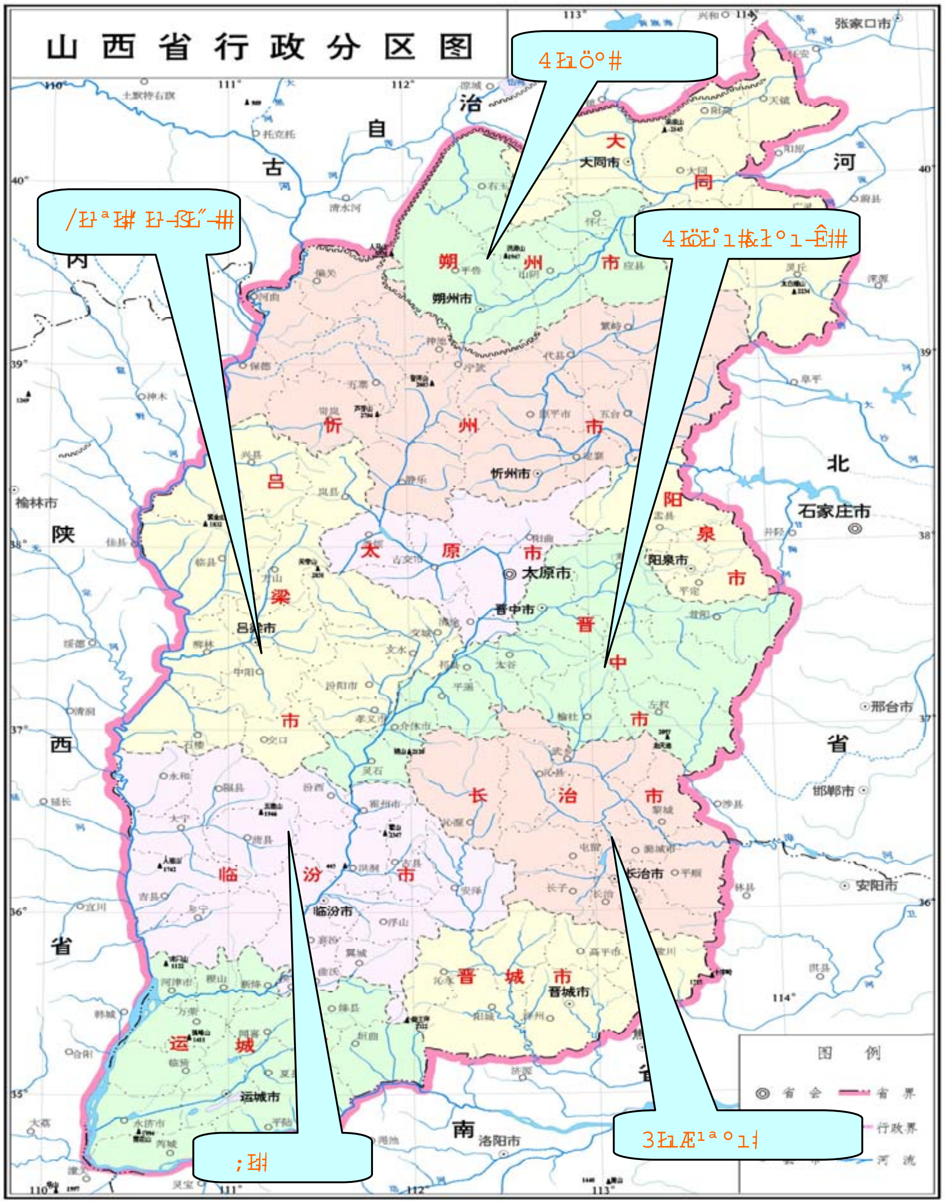

Figure 1. Location map of the demonstration project countries.

2. Opportunities: interventions in the lowland areas

Intensive farming activities in the lowland areas of the Shanxi province have created a situation of unsustainable groundwater use in a water scarce area. This poses a threat to the economic development of the area. The new challenges related to groundwater overuse and the coping strategies in lowland areas have been studied in Qixian and Qinxu.

2.1 Qixian - efficient greenhouse irrigation in the plains

Qixian is typical for the central farm belt of Shanxi – the main grain basket and source of vegetables and livestock products. Farm incomes are relatively high in Qixian. They stand at RMB 14704 per farm family member. The lack of an industrial base in Qixian is compensated by intensive farming activities that includes poultry and cattle fattening.

The agricultural prosperity in Qixian county however is built on a foundation of unsustainable groundwater use. The area is clearly water scarce: it has an overall per capita availability of 263 m3 and a useable availability of 163 m3 – all clearly below the so-called 'Falkenmark Indicator' for water stressed areas (500 m3 per capita). As surface water is limited and polluted the larger part of water used is from groundwater. Yet groundwater has been overused for a long time – at a ratio of 173% of the recharge in 2010. The inevitable drop in groundwater levels is 0.76 meter in an average year. The need for more efficient irrigation and higher productivity within a framework of regulating and reduced groundwater consumption is obvious.

The pilot installation of Xiliuzhi Village is at short distance from the county capital. It introduced efficient greenhouse irrigation that can serve as an example for a larger area in the central plains in Shanxi, reaching much higher water productivity than hitherto achieved and reducing pressure on the use of groundwater. In the village at present 15 hectares is covered by greenhouses – supplied by wells set at 150 meters depth. Greenhouses in Xiliuzhi come in two varieties. First are semi-arched traditional structures that have a three meter mud wall on one side. Thick straw blankets are positioned on top of these – rolled down and insulating the green house at night. These greenhouses come at a cost of Y56000 per standard unit (667m2 or ī1.1 mu). The second type of greenhouse is lower in cost. These greenhouses consist of (removable) arched plastic sheds and are installed at a much lower price of Y10000. These plastic shed are only used in the warm season as it is not possible to shelter them from the cold with straw blankets as in the semi-arched structures.

Prior to the installation of the micro-irrigation systems under the pilot flood irrigation was common in the greenhouses. Water was distributed from a small canal running across the length of the greenhouse. In the pilot these flooding systems were replaced with state of the art drip irrigation systems. These consisted of (a) central control unit; (b) buried pipeline connection and (c) drip systems within the greenhouses. The central control unit was equipped with pressure meters, double distribution lines, a centrifugal filter to remove impurities from the water and a frequency converter. The frequency converter is an innovation within the greenhouse systems. The converter adjusts the current to the demand of the system. In this way an energy saving of 40% over conventional power systems is realized. Whereas in the last five years the use of frequency converters in industries has become widespread, in irrigation its application is very new.

The control unit is operated on the basis of voluntary self-management by the Water and Electricity Service Association that operates under the guidance of the Village Administration. Apart from operating the equipment the Service Association takes care of the irrigation scheduling as no more than four greenhouses can be provided water at the same time. Farmers pay for water and electricity – the cost of the former set at 0.6Y/m3. From the central control unit the water is led through buried pipelines to 39 traditional greenhouses and 20 arched structures under the pilot. Water supply in each greenhouses is independent – with their own water meter, electricity meter, additional second filter system and connection for a fertilizer/ pesticide mixing unit. The emitters are regularly spaced at 50 and 70 cm to allow the cultivation of vegetables. On the control houses next to every greenhouse unit the main messages on water and fertilizer applications in different parts of the season are painted. Prior to the operation training was provided to the farmers on the use of the drip systems. The cost of this installation amounted to USD 45600 (under the ADB grant) with supplementary funding of Y210000 by local government funding from improvements to the main water source. The expected life span is 8 years.

The drip systems are used in combination with inexpensive plastic mulch. The main benefits are the saving in water and fertilizer usage. Water supply for the traditional greenhouses is set at 11m3/hour; for the arched greenhouses at 8.5 m3/hour. The water saving amounts to an estimated 40-60% or 200 m3 for the semi-arched greenhouses and 150 m3 for the plastic sheds. Fertilizer consumption is reduced with 35-40%. Moreover, the more accurate applications translate into an increased crop yield of 25-40%. Water productivity (the 'crop per drop') improves with 90%. Some crops such as zucchini are particular sensitive to this type of precision farming: they would do not do well without these improved systems. These estimates are based on limited farmer interviews but would need to be confirmed in more detailed monitoring.

In money terms the estimated benefit is an additional profit of Y10000 per year per traditional greenhouse. This compares favourably to the investment per hectare of Y4000 per greenhouse or Y6000 if all investments are included. For semi-arched structures the benefits are less as they are not suitable for winter cropping as they cannot be insulated – gross benefit is Y5000 and net benefit Y2000. Very important are also the labour savings estimated at 80% - as the drip systems made it possible to do away with the time-consuming flood irrigation.

The Farmers Union in Xiliuzhi has already started the development of a second system that is a copy of the pilot installation. The new system is funded entirely by farmer members. The system under construction even will be three times larger than the pilot with 102 traditional greenhouses and 57 arched greenhouses having subscribed to it. There has been much interest in farmers of other areas visiting the system and the plan is to fully cover the area with improved drip systems by 2013. A shortage of investment capital – not enthusiasm – is the main bottleneck.

2.2 Qinxu – regulating groundwater use

Qinxu has traditionally been an agricultural county, administered under Taiyuan city. The total population of Qingxu County is 340,000, of which the agricultural population is 250,000. The County has arable lands of 419,500 mu. The irrigated areas amount to 368,000 mu, among which 34.1% is irrigated with groundwater. The economic and agricultural development of the area has led to an annual water shortage of 45.36million m^3. Until 2005-2010 the groundwater level has declined at 1.6m per year (Li Futian 2011). Due to the importance of groundwater for the county's economy and the urgent need to avoid groundwater over-exploitation Qinxu County established a sound mechanism for water resource allocation, management, evaluation and monitoring of groundwater (Li He 2011).

The Qinxu Groundwater System was put in place in 2007. What it has done is that it has equipped all 1473 wells in the county with an automatic operating system that a farmer will operate with his swipe card. The amount of water that can be used is based on quota that are given out annually.

The quota are determined first per sector (industry, agriculture, domestic and environmental) and then for each of the 197 villages within the county and finally for each farmer within the village. The quota varies from area to area and depend on the groundwater resources sustainably available. The quota for individual families are based on the land owned, the number of family members and the livestock owned. If water is used within the quota the price is ¥ 0.41 (Euro 0.05) per unit. If it exceeds it is ¥ 0.55. The unit relates to the electricity units consumed. As some wells are very shallow and others are deep the volume of water against a unit may vary from 500 to 5000 litres.

Water fees are used to pay the electricity fee for pumping the water, the salary of irrigation management and for maintenance of the irrigation facilities. The over quota water fees are used as to pay any left over debt of the electricity fee or the salary and then allocated for 50% of repair costs. The balance of the funds is for developing new water resources (Li He 2011).

The water price is quite expensive when compared with the cost of planting and the potential profit. This ensures the price signals are effective. In Xihuaiyuan village, the water fee per mu comes down to ¥ 73 yuan (water consumption=240 m3). According to the national statistics, in 2008, the cost of planting wheat is ¥ 274/mu, and the net income only ¥ 296 /mu; the cost of planting corn is ¥ 232 /mu, and the net income is ¥ 423/mu (Li He 2011).

Quota are also traded – between villages and between farmers. There is an upper limit to the price (twice the basic amount) – which cannot be exceed. Among farmers it is more common to share 'excess water' with family members and neighbours than to trade. As in other cases, the absence of groundwater markets growing water scarcity has not lead to monopolization of the resource (Aarnoudse et al. 2012). In general, however allocation of the quota is quite tight for irrigators. According to the quota regulations, any left over water also can be kept for the next year. Even though a farmer does not use up the water quota, he would like to keep it for next year. This reflects that farmers do care about the quota and the price ladder.

The swipe card transactions are transmitted through internet to the Digital Water Resource Information Centre in the Water Resources Bureau of the county. This centre meticulously record the number of units consumed by each farmer based on his swipe card transactions. A farmer may use water from more than one neighbouring well. If a card is lost it can be easily replaced as the Information Centre keeps the records for several years. The Information Centre is also connected to sixty solar powered observation wells that transmit data on groundwater levels on a continuous basis.

The results are remarkable. In spite of the tight restriction 70% of farmers rated the new system as good, the majority in fact as very good. As the swipe cards have to be pre-loaded cost recovery is 100%. What is even more significant is the effect on the groundwater. Whereas prior to the system being developed (at a cost of ¥ 30 Million (Euro 3.75 Million or Euro 251 per hectare) groundwater levels were in heavy decline, this has been turned around and groundwater levels have been increasing with 1.6 to 4.8 meters a year. Also the volume of groundwater consumed was lowered steadily: from 59 Million cubic meters in 2004 to 30 Million cubic meters five years later – a drop of 40%. The regulated system encouraged farmers to adjust farming practices (Li He 2011): better field preparation (81%), use of plastic mulch (61%) and change of varieties (49%). Awareness on pollution risk from fertilizers and pesticides has also been built from government communication campaigns. Finally, the implementation of the project enhances the efficiency of water use and its benefits, and promotes the sustainable utilization of water resources. The increasing contradiction between the supply and demand of water resources has been alleviated. The groundwater environment has recovered from continuous worsening (Li Futian 2011).

3. Opportunities: higher water productivity in the upland areas

Poverty is concentrated in the hilly rural tracts of Shanxi. At the same time there is still potential to expand farming, as in contrast to the lowlands, water resources are not overused. What is important is to introduce systems with high water productivity (monetary output per unit water), that expand the range of crop option in these areas and are adjusted with the aged composition of the rural population – i.e. that are labour-saving.

3.1 Xi – developing horticulture in the loess plateau

Xi county ranks among the 35 most poor counties China-wide. The population counts 107,000 - spread over 8 townships and 97 villages. The rural nature is obvious: 80,000 of the residents are farmers. The average per capita farmer income is RMB 2496 – close to the level of the poverty line of PRC. 53,000 persons in Xi county in fact are living below the poverty line.

The county is part of the large Loess Plateau and is highly accidented – consisting of eight separate plateau areas. Since 1979 considerable work has been done on the rehabilitation of the vulnerable catchment – with 1 million mu treated and a similar area still to do. The costs of this is approximately Y5500/mu – but varies widely: on the flat plateau areas it is Y1500/mu, but on the sloping areas it is considerable higher though coast have been reduced with the increased use of bulldozers. In areas with a slope in excess of 25 degrees only reforestation is undertaken. The impact of the loess plateau treatment has been very positive. Compared to 1979 when the program started:

- Soil erosion reduced with 1320 ton per square kilometre per year
- Retention of surface water increased with 26.8% (from 14 to 40%)
- Interception of sediment increased with 32.5% (from 17.5 to 50%)
- Forest cover increased with 32.8%

Xi county has a climate that is suitable for high value fruits, in particular pears, apples and apricots. The 'Golden Pear' from Xi County enjoys national fame and was already served in the royal courts of the Ming and Qing dynasties. It was also selected as one of the speciality fruits for the 2008 Olympics. The climate (average 8.9 degrees), the large variation between night and day temperature (causing sugar levels to increase) and the excellent thick loamy soils (with good aeration) presence of large number of varieties (close to 100 varieties of pear for instance) explain the comparative advantage of the county. The area under fruit trees is heavily promoted: the target is 350,000 mu of which 310,000 mu is reached. Xi county's economic strategy is very much based on 'speciality' agriculture – it has no industrial or mining base, but has 430,000 mu of arable land. Rainfall is 570 mm a year but variable and there are 150-170 days without frost.

Promotion has consisted of (1) promoting new plantation and better water resource development (2) introduce better agronomy – including better fertilizer usage and grafting (3) promote intercropping by crops that are low in height such as chrysanteum and beans (4) improved marketing both better storage at farmers levels and developing new marketing canals.

Production is however held back because of the dependence on variable rainfall. Irrigation is limited – not more than 4400 mu and in several cases suffering from insufficient performance and management. Farmers often resort to irrigation by bucket from local water points but also given the relatively old age of farmers there is not much that can be achieved with such methods.

The pilot under 0188-PRC was developed in Quyan village – close to the Wulu Mountain range - that counts 120 households and 514 people. The arable area belonging to the village is 2800 mu – used for corn/ millet/ sorghum/ beans and potatoes and cash crops in particular pears, herbs and oilseeds. Under the demonstration project 250.5 mu (serving 52 farm households) was developed on a comparatively level area – yet with a height difference still of 20 meters. Such slopes made furrow irrigation – apart from its inefficiency – impossible.

Under the project instead a so-called 'spring system' were developed – with 0.8 mm diameter supply pipes making clogging unlikely. Each spring pipe outlet is feeding a circular pit excavated around a single fruit tree.

The spring pipes are supplied by pvc hoses laid out over the orchard area. These flexible lines in them selves are connected to outlets on the main pipeline feeding the area. The length of this main pipeline is 2320 meters running along the entire length of the 250.5 mu area. There are 58 wells on the pipelines to serve the water lines to the orchards. The diameter for the main pipeline is 110mm. Earlier this was 90 mm but then there was insufficient pressure in the system. Two thirds of the pipeline has been replaced.

The water comes from the spare capacity of the village water supply system – that besides the agricultural areas is feeding six small village clusters. The source of the system is a spring located at lower alleviation with water being pumped up through a largely buried pipeline to a central tank. Part of the pipeline is exposed though and drainage wells are there to empty the main supply line and avoid it busts in heavy frost. For the micro-irrigation system a small central unit is in place besides the central tank – to regulate pressure and with a centrifugal filter to clean the water. There is also the option at this central unit to add fertilizer or pesticide to the irrigation water. The main water supply system is operated by the County Water Resources Bureau whereas the village committee takes care of the irrigation system. Training was provided on two occasions.

The pilot in Quyan village has received a very enthusiastic reception by local farmers. The piped micro-irrigation 'spring' system makes it possible for the mainly aged farm labour to grow irrigated orchards. Earlier this was done by hand-carried cans – but obviously there is only so much a farmer can do. The expectation is that with the spring system a yield of 1500 kg/mu can be reached with a sales price for apples/pears of RMB 5/kg – creating a production value of RMB 7500/mu. Without irrigation yields are closer to 600 kg per mu. The cost of the pilot amounted to RMB 335,000 (exceeding the grant amount of RMB 238,000) – yet very favourable at RMB 1350/mu. The payback period hence is short. The pilot fits well into the plan of the local government to expand the area under (irrigated) high value niche horticulture, provided small local water resources can be developed and tapped into. The plans at county level are eventually to have 160,000 mu under improved irrigation system, but this will require a careful planning and development of local water resources as well.

3.2 Pingshun – creating a controlled environment for speciality crops

Pinghsun is a mountainous county located in the southeast of Shanxi. It has population of 164,000 – the majority of which depends on agriculture (135,000). Most of the 12,920 of arable land is rain-fed with irrigated land amounting to 10%. Groundwater resources are as yet not much used. The county has several mineral resources (silica, aluminium, commercial clays) and plans for sustainable energy (wind, solar) as well as tourism potential. The main economic base, however, for the time being is agriculture – the main crops being commercial trees (walnut and prickly ash) and annual crops such as rice, wheat and legumes. The area is also classified as a poverty county. Its GDP per capita is RMB 7658 but farmer incomes are substantially lower at RMB 2720 per capita.

Efficient pressurized irrigation systems are often promoted to save water but their largest benefit in fact may lie in the higher production they make possible. While this is not new (for instance the international so-called Comprehensive Assessment on Water Resources estimated already that micro-irrigation systems achieve 5-56% higher yields), it often goes unnoticed.

A very good example of the multiple added value of pressurized irrigation system is the micro-sprinkler system introduced under the grant project on farms of prickly ash (*zanthoxylum*). This thorny scrub is usually grown for the typical peppers it produces that are the main ingredient in the famously hot Sichuan dishes. In Pinghsun however prickly ask is grown not for its pepper but for its young tender leaves. This is a relatively new niche product, sold as pickles and also as a fresh delicacy in the growing urban markets. The cultivation of prickly ash shoots received a main impetus from a local enterprise that processes the crops and is providing farmers the required upfront investment in the seedlings and equipment. Prickly ash got a major boost in Pingshun six years ago when the local government introduced the use of mesh tents. This helped to largely control the problem of aphids (lice) and reduced the use of pesticide and improved the quality of the product. A further improvement in the cultivation of prickly ash shoots, introduced under the Grant Project is the use of micro-sprinklers – suspended in the mesh tents. This was experimented in three areas: Wangli (31 farms/40 mu), Wangqu (38 farms/ 50 mu) and Henantan (100 farms/ 130 mu). Under the new irrigation system the suspended micro-sprinklers not only irrigate but also wash down the remaining aphids. The micro-sprinklers can be also connected to small mixing tanks within the mesh tent that make it possible to add small doses of fertilizer or pesticide. The controlled system also avoids that soils get too wet. As a result less fertilizer, pesticide and water (estimated at 40%) is used and a higher yield with a cleaner product is achieved (estimated 20% more). The strength of the system is not water saving as such, but also energy saving (less fertilizer and pumping) and creating a controlled micro-environment that allows a higher production.

To source water to the prickly ash shoot farm areas two water source systems were developed pumping water in one case from an improved well near the river and in the other case (feeding the two smaller areas) directly from the river. Two storage tanks were built on the nearby mountain slopes, one measuring 380m3 and one 250m3 – served in total by 4000 meter of pipeline. All these costs were taken care of by the local government contribution. It turned also necessary to include a gravity hammer in the system – this was provided under the grant project. Within the irrigated area a distribution network was laid serving distribution wells (169) in each of the prickly ash tents. Within the mesh tents a network of suspended lines with micro-sprinkler was laid out. The distribution well are equipped with the water meter and a mixing point for fertilizer and pesticide. The total investment was RMB 1.07 M – hence close to RMB 5000/mu. Of this the ADB grant was used for the field pipelines and micro-sprinklers within the farm area. This amounted to RMB 247,000 or RMB 1150/mu.

The expected income increase is 15-20%, which will be achieved at a much reduced labour input. The micro-sprinkler will also bring a much better quality green leave product – as many aphids are washed out and pesticide use can be very much reduced. The local government is keen to expand the micro-sprinkler system on all prickly ash shoots farms in the area and also experiment with other vegetable crops. One lesson was the need for intense communication and discussion with farmers – as the system is very new and requires convincing and good understanding in its usage.

3.3 Lishi - developing cold weather irrigation

With demand for fruit and vegetables increasing all over China, greenhouses have also made an appearance in more unlikely cold weather areas such as Lishi county in the Lvliang Mountains. Lishi has a continental monsoon climate with very cool winters and in some years not more than 130 days without frost. A large part of the rural population depends on (temporary) jobs in industry or mining. Agriculture makes up 3% of the GDP of the county but the proportion is increasing, largely due to the energetic development of cold weather greenhouses and the recession affecting the other sectors. The main economic base however is in coal extraction and in industry (industrial turnover standing at RMB 3 B for instance).

The rural area is poor with farm incomes at RMB 1106 – far below PRC's poverty line of RMB 2293. Water availability per capita is limited at 324 m3/year. Still only a relatively small part of the water resources are used in Lishi county. The area is very accidented with only 5% of the land being arable – with flat areas and valley bottoms used for the cultivation of maize and vegetables and the keeping of livestock. In the hilly area replanting is taken up – among others with walnut trees.

The greenhouses in Lishi resemble the semi-arched structures common in other parts of the Province - but several modifications are made to deal with the cold winter weather. The loess mud walls are thicker (4 meter instead of 3 meter) than usual. At night many of the greenhouses are insulated with thick cotton blankets that are skilfully moved over the semi-arched plastic roofs. The area under such cold weather green houses has expanded rapidly to 500 hectares in the last five years in Lishi and the target is to triple this.

The challenge is not only the temperature of the air but also the temperature of the irrigation water. As a rule of the thumb if irrigation water is colder than 10 degrees Celsius plants will not do well. The reason is that the root hairs of the crops do not develop and many of the micro biota activity in the soil stops to function. This is particularly fatal for young seedlings. In Lishi, however, the river water for large part of the winter is close or even below zero.

After a winter season of taking measurement by a team from the Taiyuan University of Technology a warming system for the greenhouse area of Xiaoshentou (altitude 975 metres) was developed under the 0188-PRC grant. This warming system in cold area greenhouses can serve as an example for many cold weather regions of the world. First water is used from a relatively warm source - in this case an underground spring along the Dongchuan River – stored in a 200m3 reservoir. The advantage of the spring water is that is still around 5 degrees at the coldest time of the year. The spring water is then conveyed through a buried pipe to the horticultural area where it is collected in a closed storage pond. The water is distributed at a control station and is also filtered there. From here the water is distributed to separate greenhouses. In each greenhouse a small plastered brick masonry pool is constructed measuring 2.75 by 1.75 meter and a depth of 1.20 meter. If water is kept here for 48 hours it will have warmed up enough to irrigate the greenhouse area measuring 1600 m3 through a system of regularly placed drips under plastic mulch (for vegetables) or through suspended micro-sprinklers (for oyster mushrooms). The pond is built at ground level with a small rim of 25 cm to avoid dirt falling in. It is covered with a mesh for the same purpose and also to avoid the growth of algae in warmer periods of the year. Underneath the concrete structure geo membrane is used to avoid leakage. The dimensions were chosen to as not to take too much space and at the same time maximize exposure to sunlight and earth warmth. The dimensions ensure that the water temperature near the bottom of the pond is in excess of 10 degrees so that it can feed the green house irrigation system with the help of a small submersible pump. Two other designs were considered. One other option was a deep cistern but this would not warm up the water sufficiently. The other was a raised tank yet this would be more costly and would not make use of the insulating effect of the ground.

The underground tanks and micro-irrigation system make it a possible to grow a third crop in the greenhouses with at an extra annual turn-over of RMB 5500/mu, already more than the cost of the greenhouse installation. In addition the more precise irrigation and controlled environment that the drip and micro-sprinklers provide are – as in the other pilots – expected to reduce the costs of agricultural inputs and the amount of labour, whereas the crop yields are expected to increase. Because the system became operational very recently it is too early to make indicative statement on this for the installations in Xiaoshentou – but farmers predictions is that crop yields may increase with at least 10% and fertilizer and pesticide consumpton be reduced with 20%. Labout inputs would drop even more.

Whereas the project provided installation in Xiaoshentou, improved systems have also been constructed in the other greenhouses in the area. These however use an older version of the warming pond consisting of a small elevated tank within the greenhouse. All in all under the 0188-PRC grant drip systems were installed in 29 greenhouses (standard size 1.1 mu) and micro-sprinklers in 17 greenhouses (total 1.93 ha). The cost of this (including the control station) was RMB 245000 – or around RMB 5000/mu. In addition from the local government funding RMB 3 M was spent on the main water supply systems – that however serves the entire greenhouse area (3.3 ha).

In spite of the high cost, the scaling up potential is high in Lishi, as there are ambitious plans to develop irrigation sources and construct more cold weather greenhouses.
One area of concern in Lishi, as in all mountain area, is to have a good understanding of the fragmented water resources in the tracts. The availability of adequate amounts of water – in the different parts of the year – needs to be carefully observed and assessed, also with the changing rainfall patterns in Shanxi.

4. Conclusions and recommendations

Most of the systems became operational in the course of 2012 (Lishi, Qixian, Xi and Pinghsun) and this paper documents the first experiences. Given the significant challenges on the North China plain the pilots are promising – to say the least.

The modernized efficient irrigation systems in Qixian, Xi, Pinghsun and Lishi achieved a more judicious use of water but equally important they helped to increase yields by creating a controlled micro-environment. These demonstrations made a quantum leap in water productivity possible. The effect was double edged: the new system reduced water use and increased yields at the same time. The improved systems in Xi, Pinghsun and Lishi also introduced and facilitated high value farming in relatively difficult but water rich areas - without these innovations such farming systems would have been difficult. Furthermore the demonstration activities greatly economised on the use of agrochemicals and labour – this capitalizing on the demand for quality food and also fitting in with the aged nature of PRC's agriculture labour force. Their success was also apparent from them being imitated. With short payback periods and additional benefits, these innovations are set to travel easily– especially in horticulture for which they are very best suited.

In addition the Qinxu systems through tiered and heavy pricing system and highly efficient 'swipe card- based regulation also created the incentive for 'a water conservation society'. The Qinxu model set the stage for farmers to invest in efficient water management – resulting in a considerable water savings, in staple crop areas, for an entire district which is nothing short of impressive Interventions at this scale are also highly necessary and worthy of more support. As the systems is large and require upfront investment in time (intensive discussion with all stakeholders) and money (the investment in the new infrastructure) there is a strong case for governments and international financial institutions to invest in such scaled up models. Regulation such as Qinxu is moreover necessary: without it the introduction of efficient irrigation runs the risk of encouraging an expansion of irrigated area – and with it an increase in water usage.

The pilots can also make a significant indent in water consumption in agriculture, still the largest groundwater user in Shanxi. In additional, more measures and a comprehensive plan are necessary to bring groundwater use back in balance and bring the resource economy back from the brink.

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