Prospects on Drip Irrigation Development in Xinjiang, China

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Abstract. *China's Xinjiang Uyghur Autonomous Region is one of the extreme arid regions in the world and has been suffering from severe water scarcity problems for decades. In the last 20 years, application of drip irrigation technique has been expanded rapidly in the region from zero hectare in early 1990s to more than three million hectares at present which accounts for approximately half of the cultivated area of the region. While the widespread adoption of drip irrigation temporarily addressed the water scarcity issues and improved the crop production, it brought issues that should be addressed and resolved in the near future to ensure the sustainable development of agriculture and food safety in the region. This paper summarized the current status, and identified problems and challenges that widespread adoption of drip irrigation has brought to the agriculture production and environment at a regional scale. A number of technological and policy solutions were also identified through the study and several integrated water management strategies were proposed for the sustainable agricultural production and environmental protection in the region.*

Key words: Drip Irrigation, Adoption, Development, Arid Region, Xinjiang

1. Introduction

The arid regions occupy a vast area in northwestern China with the total area of 2.5 million km^2 or one-quarter of Chinese territory. These regions include the western part of Inner Mongolia, the northern part of Ningxia Hui Autonomous Region, most of Qinghai and Gansu provinces and the Xinjiang Uyghur Autonomous Region (As shown yellowish area in Figure 1). In these regions, mean annual rainfall is less than 250 mm, further reduced (50-150 mm) in the western plains and reaches the lowest (less than 25 mm) in the Taklimakan Desert in Xinjiang. The annual evaporation is more than 1,400 mm in general, and about 2,000-3,000 mm in desert areas. Because of the arid climate, about 70 per cent of the total arid regions are unusable areas such as sandy deserts, gravel deserts, and other wildernesses (Chen, 2014). Compared to other region of China, the arid northwestern China is relatively less developed and the local economy depends only on irrigated agriculture and animal husbandry. Water is not only the most precious natural resource in this region but also the most important environmental factor of the ecosystem. Since ancient times, water utilization has always had a decisive impact on local socioeconomic development. But the increased intensity of human activities and overdraft of water resources caused, and quickly spread, agro-environmental degradation, including salinization, vegetation degeneration, and sandy desertification. The shortage of water resources has become a "bottleneck" restricting agricultural production and economic development. To ensure national food security, China has been developing water-saving agriculture since last decades in these regions. Particularly, the central government has been mainly promoting the adaptation of drip irrigation technology in the Xinjiang Uyghur Autonomous Region (Xinjiang) where is the country's main cotton and grain production area.

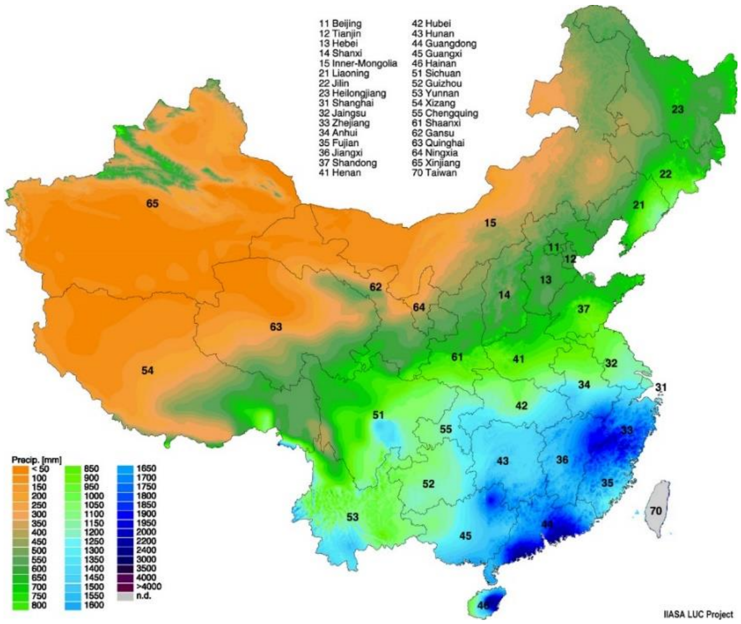

Figure 1. Average annual precipitation in China (Institute of Soil Science, 1986)

As one of the world's largest arid places, Xinjiang is situated in northwest China. Located in the hinterland of the Eurasian continent, it has world's second largest Desert-Taklimakan desert that located in the southern part of Xinjiang (as shown in Figure 2). The topography of Xinjiang features three mountain ranges and two basins: The Altai Mountains in the north, the Tianshan Mountains running through the middle of the region, the Kunlun Mountains in the south, Dzungarian Basin and Tarim Basin between the three mountain ranges. Xinjiang's total annual water resources of 83.2 billion m^3, the unit area of water production is only $5m^3$ / km^2, ranks the third from the last in the country. The total water resources utilized in social and economic sectors is 61.7 billion m^3, of which the agricultural water consumption is 59.18 billion m^3 that accounts for 95.8% of total water in use (Gao and Shi, 1992; Liu et al., 2013). In 2014, total economic and social water consumption in Xinjiang is 58.18 billion m^3, of which agricultural water consumption is 55.09 billion m^3 (94.7%). As of 2011, the total cultivated land in Xinjiang is 4.12 million hectares, accounting for only 2.5% of the total area (Xinjiang Water Resources Research Institute, 2015). The desert, barren land, and other unused areas totaled around 102 million hectares which accounts for the large proportion of unusable land in the region (Chen, 2014). Hence, Xinjiang's agriculture is typically an oasis agriculture under the dual constraints of water shortage and landscape structure that limit agricultural production. With its population growth and intensifying agricultural activity, the Xinjiang region is facing threats of water security as other parts of the world that have similar climate and environmental conditions, such as Israel. Another challenge that will only worsen the region's growing water woes: melting and shrinking glaciers. The Tarim basin, the main agricultural region in Xinjiang, is one of the driest geographical places that relies heavily upon water sourced from the melting glaciers in surrounding mountains. Climate related drought and human activities have significantly contributed to the region's dwindling water supply.

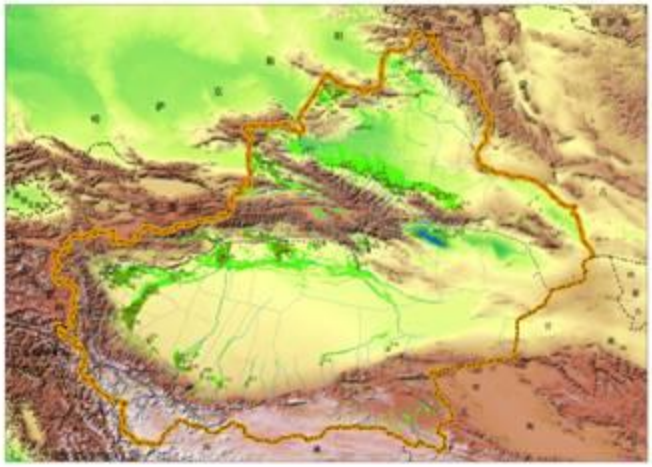

Figure 2. Topographic map of Xinjiang, China with green color shows cultivated area (Xinjiang Institute of Ecology and Geography, 2009).

In the last decades, the canal restoration, improved drainage systems and a switch to drip irrigation has helped to enhance water conservation practices within the area. However, water use efficiency is still low, agricultural irrigation water accounts for more than 90% of the total water consumption and produces only 20% of the total GDP of the region (Chen, 2014). Hence with all the odds, it seems that widespread application of efficient irrigation technologies is the only option to conserve the limited water and land resources in the region. The first drip irrigation program was introduced from Israel in 1994 to start use of the world's most efficient irrigation method in the region (Abudu, 1997). For the last 20 years, with the help of Israeli drip irrigation technology and with the implementation of the national western development strategy, the widespread utilization of drip irrigation in Xinjiang has been undergone intensively. The area irrigated with drip irrigation technique has been expanded rapidly from zero hectares in early 1990s to more than three million hectares at present. The Xinjiang has become world's largest drip-irrigated region in terms of total area and diversity of crops. Even though the widespread adoption of drip irrigation temporarily addressed the water scarcity issues and improved the crop production, it also brought issues that should be addressed and resolved to ensure the sustainable development of agriculture and food safety in the region. This paper provides an overview of the current status of drip irrigation in Xinjiang Region, identifies challenges in technological and institutional issues and proposes measures to assure the sustainable utilization of water resources and development of agriculture in the region.

2. Adaptation and Development

2.1 Periods of Development

The adaptation of drip technology in Xinjiang has been experiencing three major periods from the early 1990s to the present. They can be categorized as Demonstration and Adjustment period (1993-2000), Large-scale Extension period (2000-2010) and Progression and Upgrading period (2010-present).

The first period-the demonstration and adjustment period is mainly characterized by the introducing the drip technology from Israel, establishing demonstration projects and conducting pertinent research on the adjustment of the drip technology based on the local climatic, hydrological, environmental, agricultural and socio-economic conditions. During this period from the early 1990s to 2000, the drip irrigation technology was introduced from Israel and established demonstration projects in different areas of

Xinjiang starting from driest areas such as Turpan, Kumul gradually to southern Xinjiang, and to Tianshan North belt economic areas with large scale irrigated cash crops. During this period, about dozens drip irrigation projects were completed and the effects of drip irrigation on different crop yield was tested. Most of the extension work was focused on the testing, experiment and development of some cost-effective drip irrigation products such as basic screen filter and sand separators. During this time, the drip irrigation was mainly installed in orchards such as grapes, pearls, and field crops such as cotton due to high cost imported driplines. Considering the cost of head control system, the groundwater was used as the water source in almost all the demonstration projects due to its low filtration system cost as compared to the canal water which requires expensive filtration system for drip irrigation. The total drip irrigated area in this period is under 100,000 hectares in the whole region mainly due to the high cost of the system that can use only imported driplines and filtration systems.

The second period-the large-scale extension period is characterized by the expansion of the drip system at a rochet high speed due to the lowered cost of the system and direct provision of subsidies for the farmers from the central and regional governments during 2000-2010.The main feature of this period is local companies was able produce dripline and tapes at a very low cost. In addition, the technical assistance from Israel government and institutions moved from inner provinces to Xinjiang Region. For example, the Sino-Israeli Demonstration and Training center for Agriculture in Arid Zone was established in Xinjiang and it was the first cooperative project between China and Israel in north-west of China at the governmental level. It was the most advanced agricultural base of water-saving in dry land in China. The project has been operated over 10 years, and more than 20,000 people visited and around 6,000 people participated in the training activities that were organized there. The establishment of the farm played important role in promoting drip irrigation in the region from both technical and management perspectives. With the research and development (R & D) and industrialization of water-saving agriculture, many local irrigation manufactures start to produce better quality drip irrigation products including driplines, tapes, filtration and controlling systems. A series of water-saving products and complete sets of equipment were initially formed with Chinese characteristics and independent intellectual property rights, which promoted the rapid development of water-saving leading enterprises like Xinjiang Tianye, Fujian Yatong and so on (Wu, 2004; Wu, 2010). Dripline and drip tape producing lines were also established in huge scales, which made the cost of driplines drop from 0.20-0.40US$/m to 0.06-0.10 US$/m, with drip tapes dropping from 0.05 - 0.08 US$/m down to the 0.001-0.002 US$/m (Xinjiang Water Resources Research Institute, 2015). With the development and production of local filtration equipment, the cost of filtration system has also been reduced to one third of filtration products that manufactured abroad such as AMIAD, ARKAL filtration systems. Thus, the drip irrigation system cost was dropped drastically in this period, is about one third of the prices at end of 1990s, which in turn facilitate the wide-spread application of drip systems all over the Xinjiang. As can be seen from Figure 3 that, the total drip irrigated area increased sharply from 0.17 million hectares in 2005 to nearly 1 million hectares in the end of 2010, and this is equivalent to one fourth of total cultivated area in the whole region.

The third period-progression and upgrading period from 2010 to present is characterized by the utilization of better quality of drip irrigation products and widespread application of automatic controlled drip irrigation system. During this period, with the expansion of drip-irrigated agriculture in the Xinjiang Region, some technological and institutional concerns and issues related to large scale drip irrigation drew the attention of government and stakeholders including farmers, companies, researchers, and environmentalists. And with the growing cost of labors, a special attention is given for using better quality filtrations systems, automatic self-cleaning filtrations systems, better quality driplines and drip tapes and even semi- and fully automatic controlled systems in the drip irrigated agriculture in the region. As seen in Figure 3, the total drip irrigated area is keep expanding from 1 million hectares in 2010 to for almost 2million hectares in the end of 2015, with more than half cultivated area in Xinjiang. At present, drip irrigation is used to irrigate all the crop types successfully, including cash crops to field crops and all types of orchards. The Xinjiang region has basically formed a government subsidies-oriented and farmer's investment-voluntary financial supporting system to supplement the diversified and efficient water-saving construction system. The widespread application of the drip technology has changed the traditional agricultural practices in the region. With the expansion of drip irrigated agricultural area, the integration of new cultivation techniques has been underway with drip irrigation with help of researchers from numerous disciplines including the water conservancy sectors, agronomy, agricultural machinery, fertilizers, and even computer information technology. During this period, the drip irrigation development in Xinjiang is looking more in integration of different technologies and knowledge related to agricultural production and environment to improve crop production and quality, treating system as whole watershed instead of a single drip irrigation project. Special attention is gradually given to reintroduction of advanced agro technology from the abroad, particularly learning from Israeli experience of integrated water resources management under changing irrigation method in a regional level.

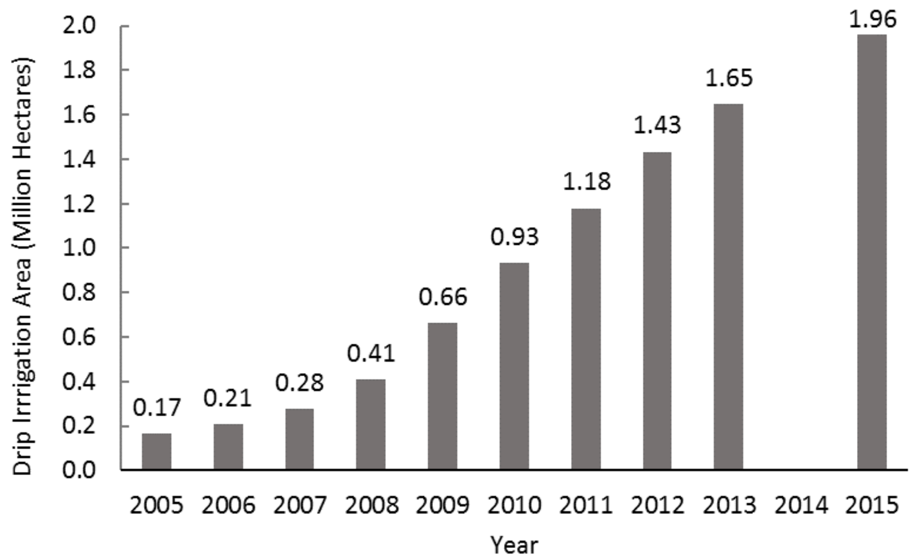

Figure 3. Development of drip irrigation area from 2005 to 2015 (Xinjiang Water Resources Research Institute, 2015)

2.2 Drivers for Development

As described earlier, the unique natural conditions of Xinjiang demand use of drip irrigation technology in the region. Although a significant cost reduction has taken place through increasing locally manufactured drip irrigation products, but the cost of investment is still far beyond the farmer's financial ability to construct drip systems by their own. Cremades et al. (2015) conducted comprehensive research on the importance of governmental support measures and economic incentives for the adoption of modern irrigation technology in China. Their results showed that the government policies and incentive mechanisms played a significant role in promoting the adoption of modern irrigation technology in China. The twenty years of drip irrigation practices in Xinjiang also indicates that the governmental support is an important factor in farmers' decisions whether or not to adopt drip irrigation technology. Governmental policies in promoting adoption of drip irrigation technology played a major role in adaptation and development of the water saving technology in Xinjiang region by providing favorable economic and technical support directly to farmers. Consistent encouragement and support has been given to local government, research and design institutes and manufacturers by the central and regional government in aiming to adapt drip irrigation technology in the whole region for the past 20 years and more. To overcome economic constraints, government direct provision of subsidies has proven to be an important policy measure in increasing the adoption level of drip irrigation technology.

In terms of technical support, providing knowledge and technical advice through extension service activities are effective ways to increase the adoption level of modern irrigation technology. In the last few decades, a rational economic incentive for farmers in the region was gradually set through various positive measures and policies such as water price reforming, marketing of drip irrigated fruits in addition to governmental support, which in turn are other important factors that influenced farmer's technology adaption behavior.

3. Major Challenges

With large-scale application of the drip technology in the region, many new issues and potential problems have surfaced that could pose great impacts on sustainable agricultural production in the region. These issues include, but are not limited to, the effects of drip irrigation on soil salinity, low irrigation uniformity due to low quality of products and poor design, lack of management of the existing systems, and the coupling drip irrigation technique with other agricultural practices such as tillage, crop structure, harvesting and soil management. Following are few important issues and challenges that should be resolved in order to assure the sustainable utilization of the techniques in the region's agricultural production.

3.1 Low Water Productivity

The challenges the Xinjiang Region faces in terms of water availability for the agricultural sector are impaired by the sector's low irrigation efficiency. Overexploitation of water resources, including excessive diversions from rivers, and overdraft of groundwater resources, causing decline of groundwater levels, is a common problem in the region (Ye et al., 2015). Average water productivity for grains is reported to be around 0.7-0.8 kg/m^3, which is much lower than the levels of 2.0-2.5 kg/m^3 recorded in the industrialized countries (Chen, 2014). Even after large-scale utilization of drip irrigation, the irrigation efficiency is still around 0.5 in the region, particularly in the southern Tarim Basin. One of the causes is that water delivery systems including main canals in Xinjiang have the long-distance delivery with low efficiency. According to the field test and evaluation in recent years, the concrete lining of the main canal can reduce water loss by 75% in Tarim Basin (Xinjiang Water Resources Research Institute, 2015), this indicates that mere on-farm application of drip systems cannot guarantee high water use efficiency. Increasing irrigation system delivery efficiencies and improving water productivity are key to better managing water resources in agriculture in the region. Measures should be taken to improve water delivery system to enhance water efficiency for the whole region.

3.2 Poor Management

With almost half of the cultivated area are irrigated with drip irrigation, the water productivity should have been higher as compared to other parts of China. However, lack of or poor management of irrigation water limited realization of the existing drip irrigation system. It attributes to: 1) the lack of practical planning and design of the drip irrigation system (Ma et al., 2010); thus, the farmers are hardly taking advantage of the constructed drip system; 2) low product quality not only increases the cost of the maintenance, but also affects the crop production and farmer's income directly, which in turn sometimes results in the abandonment of the system by the farmers and changing back to flood irrigation; and 3) weak farmer organizations. Water Users Associations (WUA) fill an organizational and institutional gap in the irrigation management system and provide significant benefits such as improving irrigation systems operation and maintenance, contributing to water savings, reducing water conflicts, and ensuring better water fee collection rates. Most of the cooperatives currently in practice are the “company + household” model, with a disproportional influence by companies (or by larger households) in the ownership, management, and decision-making. This structure also appears to be favored by local governments who tend to extend services and support to such cooperatives. WUAs coverage remains limited in the region and many existing WUAs continue to face financial, legal, and institutional challenges, threatening their sustainability.

3.3 Unbalanced Spatial Development

Development of the drip irrigation varies spatially. Until recently, most of the drip irrigated area are located in the east and central Xinjiang where is economically developed as whole. In those areas farmers have a better income and are able to invest to some portion of the drip systems, which in turn benefits the farmers with higher productivity. However, the drip irrigation area only accounts for 14% of the total irrigated area in the vast less developed area of southern Xinjiang (Xinjiang Water Resources Research Institute, 2015), where farmers are not able to invest even a small portion of the system. In these years, the government’s incentives dedicated to this area with the highest subsidies that almost cover the total cost of the drip systems.

3.4 Inadequate Scientific Research and Technical Standardization

The scientific research activities have been far behind the rate of extension of drip irrigation area. Due to the lack of stable scientific research investment mechanism, and scientific and technological innovation, it had been difficult to form a sustained scientific and technological support system. As a result, many scientific and technological issues, such as environmental impacts of drip irrigation in watershed scale, better crop drip irrigation schedule and management that suitable for the diversified natural conditions of region, and development and utilization of low-energy, cost-effective drip products, remained unaddressed. These technological challenges need to be resolved in order to ensure sustainable agricultural production and food security in the region. Another issue currently affecting the quality and extension of the drip systems in the region is the standardization of basic technology including design, products and technological measures for construction, maintenance of the drip system. Many of the existing water-saving technologies have not been standardized and technical guidance has been lacking, which makes it difficult to adapt to different local conditions such as meteorology, crop, water source and type of irrigation project, which makes it difficult to popularize and extend the technology.

4. Prospective

Water is and will continue to be one of the most challenging natural resources issues in the arid regions of China, particularly in Xinjiang Uyghur Autonomous Region that account for one sixth of total area of China. For sustainable agricultural development and, hence, economic growth and society's progress, water is the key to success in this region. As an advanced irrigation technology, drip irrigation has become a modern agricultural technology platform in Xinjiang region to facilitate precision agriculture and increase agricultural productivity. With precision irrigation and fertilization, a high-water use efficiency can be achieved with water and energy savings. The 20-year development of drip irrigation in the region proved that only through large scale, sustainable utilization of drip irrigation, the Xinjiang’s agriculture moves toward to modernization and high productivity.

Currently, the water saving irrigation, particularly the drip irrigation, is becoming primary irrigation method in Xinjiang’s agriculture. Large-scale extension and sustainable utilization of drip irrigation systems in Xinjiang are two major tasks that will be going on in near future. To accomplish this, proper strategies and measures should be taken not only in resolving current challenges and issues, but also in addressing and finding solutions for the potential problems that we may encounter in the near future for sustainable development of advanced irrigation technologies in the region. These strategies and measures could include but not be limited to following aspects:

1. Special attention should be given to effective and integrated management of the drip systems at a basin level in addition to the government's favorable subsides policy and technical support from multidisciplinary research institutions.
2. Establish and strengthen of water user's associations for better operation and maintenance of on-farm irrigation infrastructure and improved water management. Improved irrigation infrastructure with widespread adaptation of drip irrigation will be handed over to local water user's associations after completion of construction. Water user's associations will be trained and supported to ensure that they have adequate resources and capacity to operate and manage the irrigation systems.
3. Achieve the maximum benefit of drip irrigation system by improving water use efficiency with adaption and further development of drip irrigation in a basin scale and by improving water delivery system efficiency through constructing new high-efficient water conservancy infrastructure and promoting current water systems aiming to upgrade system efficiencies.
4. Government and industrial sectors should increase the investment on the scientific research and technical innovation, strengthen R&D to promote high quality of the locally made products and improve reliability of the drip irrigation system.
5. Accelerate technical standardization both of planning & design procedure and products that commonly used in the drip systems, simplify maintenance procedures with automatic control and internet technology, support extension and education to teach end users to take full advantage of the advanced irrigation system.

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