

Nominee Statement

Jiusheng Li, professor at the Department of Irrigation and Drainage, China Institute of Water Resources and Hydropower Research, has been working on improving modernized irrigation technologies for more than 30 years. As a nationally and internationally recognized expert, all his works have significantly contributed to design, management, and extension of sprinkler and micro irrigation to enhance crop productivity while conserving environmental quality in China, and other areas of the world.

1 Describe the innovation

1.1 Consumption mechanism of sprinkler water intercepted by crop canopy

Lacking of knowledge on canopy interception resulted in hesitation in selecting sprinkler irrigation as a water-saving irrigation method for both government and farmers in China during last two decades. Li and his team conducted systematic studies during 2001 to 2010 to quantify the amounts of canopy interception for typical sprinkled crops and to investigate their consumption mechanism. The results indicated that the interception varied from 0.7 to 3 mm for winter wheat and 0.8 to 2.6 mm for maize, varying with growing stages. Moreover, the evaporation of water intercepted by canopy compensated for partial loss of sprinkle water as the plant transpiration and soil surface evaporation could be suppressed by increased humidity and reduced temperature within the sprinkled field resulted from evaporation of water intercepted. Through energy balance measurements (Bowen ratio and eddy covariance methods) and modeling, the net losses were separated from the gross losses and quantified to be 4.3-6.5% of water applied during the irrigation season of maize and approaching zero for winter wheat. The net losses accounted for a relatively small portion of water applied, confirming the water-saving merits of sprinkler irrigation. A software package to determine net loss under varying environments and operation conditions of sprinkler irrigation systems was developed and registered (Copyright registration no. 2010SR040819). Li's works provided a theoretical base and a tool for determining water losses of sprinkler irrigation and contributed greatly to developing strategic planning of sprinkler irrigation and were awarded by *National Awards for Science and Technology Promotion* in 2012.

1.2 Droplet size distributions from sprinklers

Droplet size distribution from sprinkler is an important parameter that controls evaporation loss from spray and soil erosion caused by droplet impact. Li conducted extensive measurements and modeling of droplet size distributions from different shaped sprinkler nozzles. These works are widely cited, contributing significantly to literature. An exponent model for droplet size distribution from sprinklers proposed by Li et al. (1994) is cited in the ASABE (American Society of Agricultural and Biological Engineers) publication *Design and Operation of Farm Irrigation Systems (2nd edition, 2007)* whose preface states that “*This second edition is expected to meet an important need for several future decades.*” These works, which were awarded by *Science and Technology Promotion Awards, Ministry of Water Resources* in 1992, also significantly contributed to development and revisions of Chinese national technical standards of sprinkler irrigation.

1.3 Design standards of sprinkler uniformity

Li has been known to be one of the pioneers who advocate considering crop response and water dynamics in soil when establishing the standards of sprinkler uniformity. He has conducted extensive researches to investigate the influence of nonuniformity of water and fertilizers from sprinkler systems on spatial distribution of water and nitrogen in soil and crop growth in the semi-humid region of the North China Plain and in the semi-arid region of Inner Mongolia since 1992. His related publications were spotlighted as they were published and some of them have been cited continuously with more than 100 times per paper by international and national authors. He is thus leading the research on this area. A

substantially more uniform distribution of water and nitrogen in soil than that applied by sprinkler irrigation system and a less important effect of sprinkler nonuniformity on crop growth and yield, which were mainly resulted from lateral and vertical redistribution of water and solutes in soil, was observed. Insignificant influence of sprinkler nonuniformity on deep percolation and nitrogen leaching was found. Sprinkler uniformity that is lower than the value suggested by the current standards ($C_u = 80\%$) was recommended to reduce the installation and operation costs of sprinkler irrigation systems. These findings have been adopted in development and revisions of the Chinese national standards related to sprinkler irrigation and awarded by *Science and Technology Promotion Awards, Ministry of Agriculture* in 1999 and *Science and Technology Awards, Chinese Academy of Agricultural Sciences* in 2001.

1.4 Variable rate irrigation for center pivots

Li has been leading the research of variable rate irrigation (VRI), which is an emerging efficient irrigation technology in the world, in China since 2012. The first VRI system in China that includes network of soil moisture sensors and remote control unit was constructed with a three-span (142 m) center pivot. A new method to determine optimal cycle time of solenoid valves at specific travel speeds of pivot was originally proposed based on the sampling theory and patented (Patent no. 201410635754.4; Copyright of software registration no. 2014SR199156). Also, Li and his team has been authorized a patent for field positing method of soil moisture sensors based on spatial structure of soil water content, which is fundamentally important for implementation of variable rate irrigation management (Patent no. 201410814832.7). The traits of VRI system in enhancing water use efficiency and reducing deep percolation were evaluated for winter wheat and summer maize in the alluvial flood plain of China. The merits of VRI in reducing irrigation amount by 17.6% during the irrigation season of maize and greatly reducing variability of deep percolation within the entire field were confirmed, when comparing with traditional uniform rate irrigation management. Their field works suggested that AWC (available water holding capacity) can be an alternative parameter for zone identification in VRI management. These findings all significantly contributed to literature and provided a leading role in VRI research in the world.

1.5 Design of landscape sprinklers

Li has been known to collaborate with private industry colleagues to design landscape sprinklers since 2001. He holds four patents on landscape sprinklers (Patent nos. 200810090197.7; 200910080297.6; 201310192794.1; 201410391137.4) to assure that arc-controlling unit of sprinkler rotation stays in place and undamaged when sprinkler was accessed or driven by casual or misoperations, thus increasing sprinklers' service life and stability. Before 2000, all landscape sprinklers used in China were imported from the USA, Israel, and other countries. Li's newly designed sprinklers contributed greatly to the domestic industrialization of landscape sprinklers as well as water and soil conservation for landscape irrigation in China. During 2001 to 2010, the newly designed sprinklers shared about 20% of the total landscape sprinklers in China, achieving accumulative total sales of more than USD 10 million. These sprinklers were also exported to the USA, Brazil, Mexico, Iran, and other countries. This work was awarded by *The Beijing Municipal Science and Technology Awards* in 2010 and *the Awards for Science and Technology in Water Saving Agriculture, China's Agricultural Water-saving Technology and Rural Water Supply Association* in 2012.

1.6 Transport of water and nitrogen in soil under drip fertigation

Li's pioneering work on water and solute transport under drip fertigation began in 1995 when designers and users in China expressed concerns about potentially toxic rhizospheric environments caused by fertigation. His research includes design and operation strategies for injectors, laboratory and field work on the fate of nitrogen in homogeneous and heterogeneous soils, and response of plant growth and crop yield and quality to management practices of water and fertilizers under surface and subsurface drip irrigation. His empirical models to describe the released concentration of fertilizer solution from a differential pressure tank as function of operation parameters of fertigation system have been

widely adopted by domestic and international textbooks. He has also significantly contributed to modeling water, solute, and crop behavior, and is one of the first researchers who explored the nondeterministic modeling of artificial neural networks for drip fertigation. In 2003, he published the first academic book in China on fertigation: *Principles and Applications of Fertigation through Drip Irrigation Systems*. This book has been used as a textbook for graduate students at several top agricultural universities – China Agricultural University, Northwest A & F University, Inner Mongolia Agricultural University, and Agricultural University of Hebei (see [Supporting Documents, pages 15-18](#)). His coauthored training books *Fertilization Technologies for Microirrigation* and *Microirrigation Engineering Technologies* are widely used textbooks, and have helped designers and users understand the characteristics of drip fertigation. These books have also greatly enhanced the advancement of microirrigation and fertigation in China, where microirrigation acreage has increased to more than 1.7 million ha a in 2009, ranking second in the world. These works were awarded by *Dayu Water Science and Technology Awards, Chinese Hydraulic Engineering Society* in 2009 and 2010 and have provided a guide for the design, selection, operation, and management of drip fertigation systems.

1.7 Design standards of drip irrigation system uniformity

Li's significant contribution to design and evaluation standards of microirrigation system parameters is notable. Since 2004, he has led continuous and extensive investigations on the influence of drip irrigation uniformity and spatial soil variability on the dynamics of water, nitrogen, and salts as well as crop yield and quality under a wide range of environments from arid to sub-humid, for cotton, maize, and vegetable crops. Through extensive experimentation and simulations he has found that the effect of drip irrigation uniformity on crop yield and water and nitrogen deep percolation is less than expected. These works concluded that microirrigation system uniformities as low as 60%, although lower than the current standards, may be acceptable in terms of yield and nitrate leaching; and a lower uniformity coefficient can be used in the humid and semi-humid regions than in the arid regions. These findings provide a guide for design, management, and evaluation of microirrigation systems to maximize their benefits.

1.8 Efficient and safe utilization of reclaimed sewage effluent through microirrigation

With the increasing use of reclaimed sewage effluent in irrigated agriculture, Li has devoted his efforts to efficient and safe utilization of sewage effluent through microirrigation since 2007. His findings on emitter clogging mechanisms, chlorination strategies for mitigating clogging and increasing crop yield and quality as well as preventing soil degradation have all made significant contributions to the literature. Li and his team conducted extensive laboratory and field experiments to study the behaviors of pathogens in the soil-plant system and found that the potential pollution risk of *E. coli* to soil can be greatly reduced and no *E. coli* uptake was detected when drip irrigation (especially subsurface drip irrigation) was used. Using ¹⁵N tracing technique, the effectiveness of nitrogen containing in sewage to crop production was also quantified. These findings provide significant contribution to developing best management practices of irrigation with sewage effluent.

2 Describe how the innovation saves water

Li's innovations on consumption mechanism of water and nutrients applied by sprinkler and micro irrigation systems have greatly promoted the government and farmers to select sprinkler and micro irrigation as water-saving and environment friendly irrigation methods. This has significantly accelerated the extension of these emerging irrigation technologies in China, resulting in vast savings of irrigation water. The applications of his findings on design and operation parameters in sprinkler and micro irrigation systems have significantly reduced the amount of water and fertilizers used comparing to the conventional practices. His newly designed landscape sprinklers have been used in landscape irrigation in more than ten provinces of China, with a total area of exceeding 1,000 ha. Comparing with the conventional landscape irrigation, the estimated amount of accumulative water savings has exceeded five million cubic meters.

More direct contribution to saving water of Li's achievements is the best management practices (BMPs) developed based on his innovations. As an emerging technology, center pivots were increasingly used to irrigate maize and potato in semi-arid region of Inner Mongolia, China in the last decade. Lacking of knowledge on water and fertilizer management for crops under center pivots made farmers reluctant to use the new installed sprinkler irrigation systems, but return to traditional surface irrigation. Li and his team have conducted extensive experiments at various water and nitrogen levels to develop BMPs of water and fertilizers since 2011. A management practice of irrigation at 100%ET_c (evapotranspiration), along with nitrogen application rate of 160 kg ha⁻¹ was recommended and widely used in the region. Averagely, the seasonal irrigation amount can be reduced by 20-30% and the fertilizer used can be reduced by 15-20% compared to traditional surface irrigation.

Li's findings about optimal fertigation frequencies and strategies for row crops and vegetables have been widely used to increase crop productivity for microirrigation. His studies revealed that increasing frequency from a traditional monthly fertilization to a weekly fertigation for greenhouse vegetable crops can increase yield by 18% and reduce nitrogen usage by 15 to 30%. His three years field experiments in sub-humid region of Northeast China revealed the advantage of plastic mulch in saving water by 10-15% via reducing evaporation from soil surface and enhancing crop growth through increasing soil temperature at the beginning stages of maize. Using a strategy of first applying water for one-fourth of the total irrigation cycle, then applying fertilizer solution for one-half of the total irrigation time, followed by applying water for the remaining one-fourth of the total irrigation time left the most nitrate close to the source, thus reducing the risk of nitrate leaching and enhancing nitrogen use efficiency. He also demonstrated that using two or three in-season fertigation splits could meet crop nutrients requirements in a timely manner, thus increasing crop yield by 5-10% and reducing nitrogen applied compared with traditional single fertilization at the beginning of growing season.

3. Describe how the innovation was introduced and spread

3.1 Extension of BMPs for sprinkler and micro irrigation in China

Li has devoted his great efforts to extension of his findings on sprinkler and microirrigation through training, medium propaganda, and demonstration for more than 15 years. His early extension activities were mainly included in the project titled *Principles and Practices of Water and Fertilizer Management for Modernized Irrigation Technologies* from 2001 to 2008, which was awarded by *Dayu Water Science and Technology Awards*, *Chinese Hydraulic Engineering Society* in 2010. These technologies, mainly improved sprinkler and micro irrigation, had been extended around 60,000 ha in several provinces covering winter wheat, maize, and several vegetable crops. The estimated water savings was about 180 million cube meters ([see Supporting Documents, pages 19-40](#)). One recognized work is his offering vision of how drip systems and chemical injection can be used in vegetable production of greenhouse for improving crop production and quality. At the beginning of 2000's, his demonstration works at the Experimental Station of the National Center for Efficient Irrigation Engineering and Technology Research in Beijing made the farmers be aware of the advantages of drip irrigation in creating favorable environments for crops grown in greenhouse. Furthermore, he taught the farmers to use more frequent irrigation and fertigation and fewer doses of water and fertilizers when shifting from traditional furrow irrigation to drip irrigation to save water by minimizing possible deep seepage, increasing crop production, improving product quality as well as reducing the potential risk of nitrogen leaching. He regularly hosts national and international visitors to his demonstration greenhouses to share his best practices. Since 2003, Li's findings on suitable irrigation and fertigation frequency and fertilizer usages for vegetable crops in greenhouse have been widely used by the farmers around the experimental station. Approximately estimated acreage of direct use of his results was about 1,200 ha with total water savings of about 3.7 million cubic meters and fertilizer reduced of 270 tons. Currently, drip irrigation has become a popularly acceptable method for irrigating greenhouse vegetable crops in China. Li's work at its initial application stage of drip irrigation in greenhouse did make a significant contribution to its wide extension.

Li's recent extension efforts focused on best management practices for center pivots and linear move systems in Inner Mongolia and Heilongjiang Provinces where the continuously moving sprinkler systems have been increasingly installed since 2005. His extension works might start from 2008 when he, along with the US experts from University of Nebraska-Lincoln and Valmont staff, gave lectures to a one-week training course for technicians and farmers on water and fertilizer management for center pivots in Erdos, Inner Mongolia. From 2011, Li initialized a demonstration project of optimizing water and fertilizer management in Dalad Banner of Erdos with a three-span center pivot system and a two-span linear move system. Through demonstration and training, he convinced farmers the advantages of sprinkler irrigation in obtaining a comparable or higher yield than traditional surface irrigation but reducing water and nitrogen usages through using split fertilizations and reasonable irrigation quota for the widely distributed sandy soil in the region. The best management practices developed by his works were used in 330 ha of maize cultivation (ten center pivot installations) from 2012 to 2015. The estimated total accumulative water savings was 1.6 million cubic meters in the three years. Li's extension continuously extended to two counties of Heilongjiang Province from 2012 to 2015, with total acreage of about 3,400 ha maize irrigated by center pivots. The amount of water savings per hectare was about 70 m³ with a total estimation of 14 million cube meters. Currently, the number of center pivots and linear move systems in China has reached 7,000 installations with a total area of 40 thousand ha. These management practices will be implemented in a larger area and more obvious water and fertilizer saving can be expected.

Li is also known for his extension works on water and nutrient management for drip irrigated maize under mulch in Heilongjiang Province located in semi-humid regions of northeast from 2010 to 2015. The best management practice developed by Li and his team has been extensively used in more than 2,600 ha of maize field, increasing yield by 5-10% and reducing nitrogen applied from 220 to 150 to 200 kg ha⁻¹. From 2012 to 2015, the estimated water savings reached 13 million cube meters along with total amount of reduced fertilizers of 4.5 million kilograms and production increase of 20 million kilograms.

3.2 Contributions to standards, trainings, and professional communities

Li's enthusiasms in training technicians and farmers have greatly contributed to extension of sprinkler and micro irrigation in China and other countries for around 20 years. From 1995 to 1997 when the application of microirrigation in China was at its initial stage, Chinese-Israeli International Center for Research and Training in Agriculture (CIIC) that is affiliated to China Agricultural University frequently invited Israeli experts to give lectures to Chinese trainees on microirrigation. Li was frequently invited to assist the classes as a professional interpreter of lectures and an aide of experiments. He made significant contribution to the introduction of modernized microirrigation technologies to China from Israel and other countries. In recent ten years, Li gave at least one lecture each year on sprinkler and micro irrigation to the international training courses that are sponsored by CIIC, Ministry of Commerce, Ministry of Agriculture, and Ministry of Water Resources. More than 300 trainees from more than 20 different developing countries participated in these courses (see [Supporting Documents, page 41](#)). Li was invited by Pakistan government to give lectures to a training course on modernized irrigation technologies for one week in 2012. He also gave lectures to technicians and farmers in different provinces of China on sprinkler and micro irrigation. These trainings have been playing an important role in knowledge dissemination of modernized irrigation technologies in China, and other areas of the world.

Li's works made significant contributions to development and revisions of several technical standards: *Technical Code for Sprinkler Engineering (GB/T 50085-2007)*, *Technical Code for Microirrigation Engineering, (GB/T 50485-2009)*, and *Basic Parameters and Technical Requirements on Chemical Injectors Used Fertilization (SL550-2012)* (see [Supporting Documents, page 42](#)). He is a contributing author of several standards: *SL550-2012, Computing Methods of Water Budget in Soil (GB/T, 2016, in press)* and *Meteorological Grades of Water-saving Irrigation for Wheat, Maize, Cotton and Soybean (GB/T, 2016, in press)*. He is known for his efforts devoted to reducing installation and

maintenance cost of sprinkler and micro irrigation systems through optimizing design parameters in related standards.

Li has supervised eight doctoral students and 16 master degree students in irrigation and drainage engineering; four were awarded best doctoral dissertation recognition (top 15%). He has authored and coauthored more than 245 refereed articles, conference proceeding papers, and books and book chapters that have been cited more than 2,500 times by researchers from more than 15 countries (Web of Science, Google search, and other databases). In addition, he holds twelve patents on sprinklers and drip emitters. His awards and honors include one national and eight provincial or ministry level Awards for Science and Technology Promotion in China along with various best paper awards, best supervised dissertation honors, and best reviewers. His technology transfer efforts extend to Pakistan and other countries.

Li has reviewed numerous articles for national and international journals. He is currently (joint) editor and associate editor for the international journals of *Irrigation and Drainage* and *Irrigation Science*. He is a guest editor of special issue for *Irrigation and Drainage*. Li has been associate editor of Soil and Water Engineering division of Transactions of the CSAE since 2008, and is a member of editorial committees for several other journals.

4 Describe the scope for further expansion of the innovation

Sprinkler and micro irrigation that are considered as emerging irrigation technologies in many developing countries are increasingly used in the world. According to the ICID database, the total acreage of sprinkler and micro irrigation for the 45 member countries exceeded 53 million hectares in 2012, accounting for about one-fourth of their total irrigated area. With a total acreage of 6.6 million ha of sprinkler and micro irrigation, the area in China accounts for more than one-tenth of world total. Compared to its large irrigation area of about 60 million ha, however, a relatively small portion of farmlands is irrigated by these new technologies. With an increasing pressure from available water supply, the applications of new water saving irrigation technologies are expanding fast. Moreover, the trend of intensive agriculture in China provides a challenging opportunity for extension of sprinkler and micro irrigation. Recently released 13th national five-year plan set a goal of increasing the acreage of sprinkler and micro irrigation by 6.6 million ha from 2016 to 2020 that is approximately similar to the current value in China. Li and his team's achievements on efficient and safe utilization of water and fertilizers will therefore have more and more broad prospect.