CHALLENGES AND OPPORTUNITIES FOR EDUCATION IN IRRIGATION ENGINEERING

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HIGHLIGHTS

- Declining enrollments in a declining number of university degree programs in irrigation engineering are generating concern about the future of irrigation engineering expertise.
- Technical degree and certificate programs offer options for professionals in irrigation careers, especially those in landscape irrigation careers requiring licensure.
- Extension programs are evolving to include more on-demand internet-based and social media-based information delivery, as audiences have become more accustomed to these platforms.
- Addressing workforce and expertise needs in irrigation engineering is critically important, and it will involve equipping future professionals to address national and international challenges in agriculture.

ABSTRACT. *Irrigation continues to be economically important in the U.S. and internationally, yet there is concern about future accessibility to appropriate expertise and the engineering preparation of irrigation professionals for both public and private sectors. Recent and impending retirements of academic and industry leaders, losses of some important academic programs (curricula/degree programs, research, and extension) in irrigation engineering, and reduced numbers of students threaten to significantly limit irrigation engineering capacity, especially in agricultural irrigation. Some of the challenges can be met through opportunities afforded by development of distance education programs; expansion of multi-state, multi-agency, multi-university collaborations; and increasing public-private partnerships, as well as through vigorous recruitment efforts. Recruitment can be strengthened by improving the competitiveness of salaries to be commensurate with other engineering disciplines, and by demonstrating and better explaining the abilities of the irrigation engineering profession to meet future challenges related to food, fiber, fuel, and ecosystem demands of a rapidly growing global population. While access to irrigation engineering expertise, especially domestic expertise, has declined, the need for such technical support and information for practitioners has not decreased. In fact, in many cases, technical advancements from public and industry developments have greatly outpaced the capacity for applied research and extension programs to robustly evaluate technologies and deliver objective, science-based recommendations. Growing knowledge gaps and time lags have exacerbated restlessness among some audiences, increasing the opportunities for promotion of unsubstantiated claims for some products that remain unchallenged, and further confusing appropriate selection from a growing array of available technologies.*

Keywords. *Continuing education, Distance education, Extension, Irrigation engineering, Public-private partnerships, Technical support.*

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Irrigation engineering is one of the critical subdisciplines of the larger agricultural engineering profession. Irmak and Djaman (2015) provide an excellent description of how irrigation engineers, who are often from the agricultural engineering discipline, are at the forefront of developing irrigation solutions. They indicate that agricultural/irrigation engineers are uniquely qualified to integrate complex microclimate, climate, soil, water, plant physiology, and plant biophysical characteristics, and perhaps more importantly, the interactions of these factors with agricultural machinery, irrigation systems, and overall integrated crop production systems. Further, modern irrigated agriculture uses rapidly expanding advanced technologies, including automated control systems and advanced sensors, with the help of irrigation engineers who can use their engineering expertise to synthesize knowledge and skills from multiple disciplines (e.g., agriculture, engineering, computer,

electrical, electronics, and economics). According to Irmak and Djaman (2015), “Thus, the irrigation engineering profession historically has been the core profession that is well-equipped to tackle many aspects of issues related to water resources, irrigation management, and agricultural crop productivity.” Agricultural/irrigation engineers develop technologies and educational programs to support adoption of appropriate technologies and practices in the field. They integrate science and understanding of complex agricultural/environmental systems to solve problems in agriculture and natural resources. Hence, they require mastery of knowledge and applications of cropping systems and practices; agricultural infrastructure (structures, machinery, power transmission, water supply and transmission, pumping systems, etc.); engineering concepts (hydraulics, fluid mechanics, structural design); and soil-water-plant-atmosphere relationships, as well as safety, management/operation, and resource constraints. It can be argued that no other engineering profession has the background, education, and training needed to adequately address these challenges and integrate solutions comprehensively. As the pressures of global population growth continue to strain the planet’s resources and our ability to meet food, fiber, fuel, and ecosystem needs, it is imperative that we enhance efforts to train and equip a future generation of irrigation engineers.

EDUCATION AND INFORMATION NEEDS: OBSERVATIONS FROM THE FIELD

In the spring of 2017, 39 irrigation engineers and scientists from land-grant universities, USDA-NRCS, USDA-ARS, and the irrigation industry convened to discuss center pivot irrigation technologies and associated issues. Participants represented 16 U.S. states (Alabama, Arizona, California, Colorado, Georgia, Idaho, Kansas, Louisiana, Mississippi, Missouri, Nebraska, Oklahoma, Texas, South Carolina, South Dakota, and Virginia). Goals of the event included networking opportunities across the public and commercial sectors for individuals with a wide range of experience levels (early career to experienced professionals) and for various cropping systems; electronic distribution of (primarily) center pivot-related publications from the Central Plains Irrigation Conference and the USDA-ARS Conservation and Production Research Laboratory; discussion of past research developments and ongoing research activities; identification of research, extension, and educational needs; and discussion of industry status and information gaps. Portions of the discussion and outcomes were summarized by Lamm and Porter (2017) and Lamm et al. (2019). Observations included the need for publications and other information and education needs, as well as university degree and certification programs.

Numerous irrigation technology and management topics were discussed at the gathering, including both mature and emerging topics. Some coordinators, sponsors, and instructors of educational events had noted declining attendance at traditional university-led workshops, tours, and field days (Lamm and Porter, 2017). Similar trends have been observed for agricultural and landscape irrigation professionals and associated audiences. Grower panels at meetings are popular

and can offer valuable insights, provided that they can remain sufficiently unbiased and scientifically sound, though often they are not. Younger audiences are more open, and often prefer, to receive information and education via electronic media and platforms, and there is need for timeliness and concise presentation of information. It was suggested that fewer, more focused, regional educational conferences could be an option for more efficient and cost-effective communication of information, but concerns remain regarding attendance issues. It was noted that “technology farms” (aka “demonstration farms”) and large-plot research farms can be effective venues for information delivery. Some concerns were expressed over the bias (lack of objectivity) associated with technology/demonstration farms. Other questions and considerations generated from the discussion included: How well are audiences targeted? Are educators adequately adjusting the content and presentations for the various audiences (irrigation professionals, agricultural producers, regulators, industry, policy makers, urban audiences, gender/age/other demographic groups)? How can public/private partnerships be better used to address challenges related to irrigation technology development, adoption, and management? Can high-quality information produced by manufacturers be packaged for broader industry-wide educational purposes? Are the real-world challenges experienced by irrigation practitioners, producers, and their advisors adequately reflected and addressed in education programs?

Related to recruiting, training, and retaining irrigation engineering professionals, industry participants indicated a need for well-educated employees who are willing to live and work in agricultural areas. Universities need well-trained faculty and funding to retain well-qualified and experienced faculty, as well as qualified students to develop water resources and food and fiber production solutions for growing global populations. Concern was expressed that there is a small and decreasing number of agricultural irrigation engineering degree programs in the U.S., and these programs are attracting fewer domestic students. Some indicated a perception that the importance of agriculture is not adequately reflected at universities, especially at leadership levels, and perhaps community colleges will help to fill some staffing needs for the irrigation industry. It also was suggested that USDA-NIFA may be able to provide irrigation engineering fellowships to help build irrigation engineering expertise and capacity. In fact, the USDA-NIFA National Needs Fellows program provides funding to support graduate training through a student stipend and a cost-of-education allowance to the institution. Greater efforts need to be made by universities to tap into this potential funding source.

UNIVERSITY DEGREE PROGRAMS

Graduate education in irrigation engineering includes MS and PhD programs in irrigation engineering offered by Utah State University (<https://engineering.usu.edu/explore-degrees/graduate/irrigation-engineering>), while BS and graduate degrees in water resources engineering emphasis areas that include irrigation courses are offered by the University

of Nebraska Departments of Biological Systems Engineering and Civil and Environmental Engineering and by other universities.

Many university degree programs have been affected by institutional demands (i.e., legislatures and universities) to decrease the numbers of course credits required for graduation. For instance, degree requirements for a BS degree in agricultural engineering at Texas A&M University in the 1980s was ~143 semester credit hours. This requirement has been reduced to 128 semester credit hours. At the University of Nebraska-Lincoln, this requirement has been reduced to 133 credit hours. During the same period, essential “core curriculum” course requirements to include liberal arts and other general subject matter have increased. Other universities have observed similar pressures to limit credit hour requirements and expand core curricula subject matter in undergraduate degree programs. Hence, degree programs now have fewer hours to devote to discipline-specific required courses and recommended technical and science electives. For example, at Texas A&M University, formerly required general agronomy and soil science courses and irrigation-pertinent technical electives have been removed from the required curriculum in biological and agricultural engineering, and they are no longer considered pre-requisite courses for upper-level engineering design and soil and water conservation engineering courses. Thus, unless students have the foresight or guidance to elect essential additional courses, their future employers must shoulder the responsibility to provide additional subject matter and professional training to equip them for their work assignments. Of course, tradition holds that engineers are expected to augment their knowledge with lifelong continuing education and professional development opportunities. Professional engineering (PE) licensure also requires continuing education, typically on an annual or biennial basis.

In some programs, laboratory courses have also been reduced or removed, as teaching laboratories are relatively expensive to implement and maintain, and decreasing course enrollment means that although irrigation-related courses may be listed in university course catalogs, they are not being offered consistently. This presents challenges to both students and faculty who want to pursue and teach irrigation and related soil and water engineering training. Relatively few students, compared to a few decades ago, are equipped with practical experience derived from farm backgrounds or are eager to pursue traditional field-based agricultural and biological engineering career paths. Opportunities to expand access to limited irrigation education resources may be afforded through increased capacity of formal and informal distance education programs, but these do not address the needed field-based experience issues. Distance education options are expected to be especially pertinent to practicing professionals who seek to increase their subject matter knowledge and pursue distance-based graduate degrees.

Another justification for enhancing irrigation engineering curricula and related programs is that technology has advanced rapidly in recent years in designing, implementing, and managing precision agriculture components, such as variable-rate irrigation, irrigation automation, soil water sensors, internet of things (IoT) products including agricultural

IoTs (Salam et al., 2019a, 2019b; Vuran et al., 2018, 2019; Dong et al., 2013), agricultural robotics, and unmanned aerial vehicles. These technologies are increasingly used in agriculture, irrigation/water resources management, crop water stress determination, crop water use (evapotranspiration), crop water requirement estimates, and numerous other applications. These technologies are efficient and effective when properly used; however, they require a well-trained workforce for proficient implementation in commercial production fields. Agricultural/irrigation engineers can be especially helpful in researching and developing novel best management practices (BMPs) and disseminating them to producers to help producers make better-informed decisions regarding their farm operations. Thus, achieving the full potential of these and numerous other technologies in agricultural and water management operations, as well as proper interpretation and integration of the information gained from these technologies, requires forward-thinking, relevant, and high-quality irrigation research programs by universities in partnership with USDA-ARS, water planning and management agencies, private industry, and other entities. This research must then be objectively demonstrated to the end users by irrigation engineering professionals.

Integral to university degree programs, especially at graduate (MS and PhD) levels, are vital research programs. These are foundational to students’ academic development and to faculty professional development and academic career success, as well as advancing the knowledge and technology developments in the field. Research programs generally are externally funded, meaning that faculty invest significant effort toward generating funds from highly competitive grant funding sources and opportunities. Industry support for such research efforts has often been limited and sporadic. Successful programs have been able to compete well, as they effectively engage in integrated research and extension projects and collaborate effectively with multi-state, multi-agency, multi-disciplinary teams. Sometimes these efforts are viewed by industry, extension clientele, and even university students as distractions from extension and teaching responsibilities. There is opportunity to improve communication of the value and relevance of research and of integrated research, extension, and teaching programs.

CERTIFICATION AND CERTIFICATE PROGRAMS

A greater number and variety of options are available for students interested in non-degree options in irrigation career preparation as compared to the availability of university degree programs. The Irrigation Association (IA) administers certification programs (courses, exam administration, and continuing education unit (CEU) opportunities) for irrigation professionals. Agricultural certifications include Certified Irrigation Designer (sprinkler and drip/micro categories) and Certified Agricultural Irrigation Specialist. Landscape irrigation certifications include Certified Irrigation Technician, Certified Landscape Irrigation Auditor, Certified Golf Irrigation Auditor, Certified Irrigation Contractor,

Certified Irrigation Designer (golf course and residential/commercial irrigation), and Certified Landscape Water Manager (Irrigation Association, 2019a, 2019b).

Licensing is required in many states for many landscape irrigation professionals, especially those who sell, design, provide consultation services, install, maintain, alter, repair, and/or service irrigation systems, including the connection of such systems to any water supply (e.g., TCEQ, 2019; TAC, 2009). Licensing requirements vary by state; more information is available from the IA (Irrigation Association, 2020) or from state licensing boards.

In addition to certification programs, some universities and community colleges offer certificate programs to help prepare students for careers and licensure in irrigation. Examples include relatively comprehensive applied technology programs, including those at the Nebraska College of Technical Agriculture (NCTA, 2020), which represents a partnership with Reinke Manufacturing Company (<https://ncta.unl.edu/irrigation-technician-certificate>), and at Walla Walla Community College (<https://dept.wbcc.edu/irrigation/wp-content/uploads/sites/94/2018/04/WMGMT.pdf>), which offers certificates and a degree program in irrigation management. Licensed irrigator exam preparation courses also are offered through the IA, Cooperative Extension programs, and community colleges, such as the Irrigation Technology program at Amarillo College (<https://www.actx.edu/cl/irrigation-certification>). Extension programs offered by land-grant universities also provide targeted CEU programs and opportunities (short courses, workshops, and conferences) for irrigation professionals. Examples include Texas A&M AgriLife Extension Service School of Irrigation (<https://irrigation.tamu.edu>), Oklahoma State University and Oklahoma Irrigation Association (<http://turf.okstate.edu/news-files/certified-landscape-irrigation-auditor-course/>), and University of Georgia Extension (<https://ugaurbanag.com/certification/>).

Additionally, companies and manufacturers offer courses to train their employees and others to be irrigation technicians who can design, install, and troubleshoot irrigation systems (Rain Bird, 2019; Irrigator Tech, 2014). Manufacturers also offer seminars and workshops for technical service providers, agency and extension personnel to inform them of new products and to communicate technical information about their products and applications.

EXTENSION AND OUTREACH

Extension education and continuing education opportunities for irrigation professionals and end users include a range of traditional methods and venues (extension fact sheets, mass media, workshops, conferences, and field days), as well as increasingly available internet-based and social media-based outlets. Because audiences (i.e., end users and irrigation professionals) are busy and competition for their time and attention has increased, on-demand access and concise packaging of information has become increasingly important. It has become more challenging to attract audiences to attend all-day in-person meetings, especially when the programs are not offered locally (e.g., ≤ 80 km distance). At

the same time, reduced numbers of extension educators and larger geographic territories for many public and commercial technical service providers exacerbate outreach delivery problems. Efficiency of time, travel, and other resources and information packaging for convenience, accessibility, and conciseness continue to be important considerations in extension programs, despite pressure by some audiences to retain traditional in-person, face-to-face meetings. Furthermore, as the number of irrigation extension educators continues to decline, some are being asked to expand or redirect their efforts into other subject matter areas that are often perceived to have a greater societal reward. For example, even though Nebraska has the largest total irrigated area among U.S. states, with approximately 3.5 million hectares of irrigated land and more than 16,000 irrigated farms, only four extension educators spend an appreciable amount of time working on irrigation topics. Colorado and Kansas, each with approximately 1 million hectares of irrigated land (USDA-NASS, 2019), have respectively three and two faculty positions that work with irrigation engineering topics.

With so many media outlets, there seems to be no lack of readily accessible information; however, there is a broad range of information quality, and some readily accessible information is biased, unsuitable, or even incorrect. High-quality research-based information generally requires robust applied research. Field-based research is expensive and time-consuming, and research funding is highly competitive. Academic institutions' emphasis on refereed journal publications (as metrics for job performance and promotion) and intellectual property (copyrights, patents, licensing) can also delay information transfer to the public. As a result, public research programs often lag behind commercial developments, and in some cases, they cannot keep up with the demand to conduct objective evaluation of new products. Furthermore, new products may not be readily accessible or affordable for researchers to evaluate in advance of producers' questions. Industry and end users have become accustomed to rapid access to new commercial products, and they may become impatient with the sound, systematic, and slow process of academic research and outreach. However, carefully designed, high-quality research projects and extension programs require time to address the challenges that end users will experience, while concurrently protecting the integrity and unbiased nature of information. In recent years, there has been an increasing trend in the development and utilization of electronic information delivery platforms, such as smart phone apps, for irrigation management (Migliaccio et al., 2020), and further development and accessibility of data-based irrigation scheduling tools have been advocated to address global water challenges (Chaubey and Mani, 2019). While such technologies can aid in adoption of improved irrigation management through better monitoring and control in commercial production fields, the lack of personnel who have proper knowledge and experience in irrigation engineering can be a major impediment to their effective application.

Technology farms and demonstration farms have gained momentum in recent years, and their models vary in structure and scope from state to state. In some cases, govern-

ment-sponsored cost share programs and experts from industry, universities, USDA-ARS, USDA-NRCS, and/or natural resources conservation districts also contribute financial and technical support to these programs. Publicity through agencies, local news, trade journals, social media, and other outlets effectively market these events and their success stories, providing some insights into effective strategies to reach target audiences. Keys to the success of these farms include financial support, engagement of the producers and other participants representing a variety of interests, and well-coordinated marketing and communication strategies. The robustness and objectivity of the results from these farms vary widely, and in some cases are of great concern when product marketing and sales negatively affect the adoption of sound, scientific management practices.

SUMMARY AND CONCLUSION

Declining enrollments in a declining number of university degree programs in irrigation engineering, along with recent and anticipated retirements of experienced irrigation engineers, has generated significant concern about the future of irrigation engineering expertise. Increasing collaboration with professionals with complementary expertise (civil, electrical, and computer engineering and other engineering, science, and technical disciplines) alleviates some of this concern, although irrigation engineering expertise is still invaluable for integrating the various technologies into practice. Furthermore, agricultural engineers' salaries generally are not commensurate with other engineering disciplines, adding further challenge to recruiting qualified and interested new professionals into the field.

Technical degree and certificate programs offer career options for irrigation professionals, especially those in landscape irrigation careers requiring licensure. These range from technical degree and certificate options offered by traditional academic departments to community college and technical school options and even extension-based, IA-administered, and manufacturer-directed programs. These programs are expected to improve matching of skilled employees with employer needs.

Declining attendance at traditional field days and producer-targeted educational conferences reflects the changing time demands on agricultural producers and other decision makers, as well as increasing competition from industry-sponsored events. Extension programs are evolving to include more on-demand internet-based and social media-based information delivery, as audiences have become more accustomed to these platforms. Additionally, as farm operations become larger, agricultural producers are more likely to rely on crop consultants and other technical service providers. In some cases, these larger farms may even task some of their own employees to specialize in irrigation management. It is clear that target audiences, their needs, interests, and information communication preferences are changing.

Technology farms, demonstration farms, and other non-research-oriented information outlets have grown in numbers and popularity in recent years, with part of this popular-

ity attributed to changes in marketing and increased involvement from industry. However, after some strong early successes, attendance at some of these venues has declined. Interest in seeing new technologies demonstrated in commercial settings is strong, but lack of objectivity in the evaluation of technologies and practices, misinterpreted information, and misleading marketing can be problematic and concerning.

As the irrigation engineering workforce declines, especially the domestic workforce, other disciplines will readily or reluctantly fill the void. However, irrigation engineers have undergone vigorous training related to irrigation engineering fundamentals (i.e., fluid mechanics, hydraulic design, irrigation and agricultural water management, crop water use determination, irrigation system management, soil physics, soil-plant-water-atmosphere relationships, etc.). Thus, irrigation engineers complete an effective and comprehensive curriculum and related hands-on training to be prepared to address irrigation engineering and related agricultural water management and crop production challenges. Other disciplines may not have full understanding of the different variables, as well as the complex interactions of these variables, involved in effective water management and crop production. Thus, other disciplines cannot be effective in filling the irrigation engineering workforce gap, they may disseminate misleading information, and they may even recommend improper management practices (i.e., BMPs) to producers. Development of effective strategies to fill the irrigation engineering workforce gap is paramount for ensuring the sustainability of agricultural production, enhancing production efficiency, and conserving the nation's precious freshwater resources for future generations.

In summary, there is opportunity to address current and anticipated education needs in irrigation engineering, technology, and practice. Collaboration between university and commercial research programs, outreach/education programs (extension, trade school, university degree, and manufacturer directed), and agencies and end users can further identify educational needs, improve the quality and timeliness of information, and connect end users to the technologies that are best suited and most beneficial for their operations. Addressing workforce and expertise needs in irrigation engineering is critically important, and it will involve preparing future professionals to conduct unbiased, high-quality research, develop practical solutions, and effectively deliver those solutions to end users to address national and international challenges in agriculture.

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