POSSIBLE BREAKTHROUGHS
PRECISION IRRIGATION

Water application at field level can be done either by pressurized (e.g. sprinklers, drip, micro-sprinklers) or gravity (e.g. furrow, basins) systems. Around 98% of the world's irrigated area is served by the latter, despite the fact that the investment costs of both systems balance each other out after a decade. There is further scope to promote sprinkler and drip systems as they reduce farming costs and energy requirements while improving yield.

Description

Pressurized irrigation systems such as sprinkler and drip irrigation allow for better management of crop water requirements. These techniques reduce the travelling time of water between the source and the crop roots. Water conveyed in pipes minimizes evaporation losses, while applying low volumes of water directly to the crop also reduces leaching losses and maximizes irrigation uniformity. Together, these benefits result in lower water use (and costs), reduced labor requirements, lower pumping costs, and higher yields. Although initial investment costs are higher than surface water conveyance systems, in the long term both systems balance each other out.[1]

Geography

The total land area irrigated globally is estimated to be between 278 million hectares[2] and 467 million hectares.[3] Between 1.2% and 2.1% (6 million hectares) of this area is equipped with drip and sprinkler irrigation systems.[4] Most of the irrigated area is in Asia; India and Pakistan alone irrigate over 112 million hectares.[5] Gravity-led irrigation systems are still dominant, covering 95% of total irrigated area.[6] The Asian Development Bank is encouraging small farmers in China to use micro-irrigation.[7] Given dramatically decreasing groundwater tables and the still very limited application of water-saving irrigation technologies, there are great gains to be made here.

The lower efficiency of gravity-led systems compared to pressurized water distribution systems requires larger volumes of water to meet crop water requirements. Given that irrigation is largely supported by groundwater, especially in Asia, water saving technologies could significantly reduce energy use and costs in the agricultural sector.[8] Shah et al.[9] mention that India, Pakistan, Bangladesh and Nepal pump around 210 km^3 of groundwater every year through 20-21 million pumps, of which 13 million are electric and 8 million diesel. Altogether, these pumps use energy equivalent to 100 billion kWh/year, costing farmers US$ 12 billion per year. In this way groundwater irrigation contributes to more than one-quarter of India's total energy demand.[10]

[1]For example, SWMRG 2005, [2]Siebert et al. 2005, [3]IWMI 2007, [4]Reinders 2006, [5]Ibid, [6]Brown and Halweil 1998: specifically referring to China, [7]Radstake and van Steenbergen 2013, [8]Shah et al. 2003, Narayanamoorthy 2007, [9]Shah et al. 2003, [10]Ibid

Table 1

Impacts of changing from surface to drip irrigation systems in India

Crop	Increase in yield (%)	Reduction water application (%)
Bananas	52	45
Cabbage	2-54	40-60
Cotton	10-35	15-60
Grapes	23	48
Okra	72	40
Potatoes	46	0
Sugarcane	6-33	44-60
Sweet potatoes	39	60
Tomatoes	5-50	27-39

Source: CA, 2007

Energy

- Higher water-use efficiency shown by pressurized systems allows for the reduction of total energy use where water is pumped from ground or surface water in both application systems. Farmers in Maharashtra (India) using drip irrigation save 29-44% electricity over farmers using flood irrigation.[11]
- In China, drip and micro-sprinklers could reduce energy consumption by 40%[12] and fertilizer consumption by 35-40% through more efficient application and use.
- Generally, sprinkler systems require higher energy inputs than drip irrigation systems (in the range of one-quarter more). Savings can be achieved by:
  - Using low-pressure drip and sprinkler systems. In the US this can save up to 1925 kWh (US$ 137.5) per hectare per year.[13]
  - Fine tuning pumps and sprinkler and drip systems reduced energy costs by 15% for 60% of farmers in Nebraska.[14]

Water

- Drip irrigation reduces water use by 30-70% compared to surface irrigation.[15]
  - Water application efficiency under surface irrigation ranges from 50-95%.[16] However, common efficiency is 40-60% due to poor management.
  - Sprinkler and drip application efficiency is in the range of 65-85% and 70-95% respectively,[17] the latter having less evaporative losses.[18]
- 40-60% water savings have been registered in China with drip combined with plastic-mulching.[19]
- Improving water-use efficiency at basin level needs further and more complex considerations than water application efficiency at field level because of “scale effects”. At basin scale, “wet” rather than “dry” water savings have to be achieved. Wet water saving refers to the reduction of non-beneficial drainage water.[20]

Productivity

- Change from surface water to drip irrigation has increased yields of a wide range of crops in India (see table 1).
- Crop water requirements are better managed using drip and sprinkler irrigation rather than surface irrigation methods. This usually results in higher yields:
  - Pepper yields have increased on average by 30% using drip irrigation, as compared to sprinkler furrow irrigation.[21]
  - Tomato yields have increased 1 to 2 t/ha compared to furrow irrigation and 1.3 to 2.2 t/ha compared to sprinkler irrigation.[22]
- Corn yields in the US using drip-irrigation resulted in 11.5 t/ha; with furrow irrigation they yielded 9.9 t/ha and with sprinkler irrigation 10.3 t/ha.[23]
- Yields have increased 10-40% with drip irrigation combined with plastic mulching in horticultural systems in China.[24]

[11]Narayanamoorthy 2007, [12]Radstake and van Steenbergen 2013, [13]Extension 2011, [14]USDA 2011, [15]Lamont et al. 2002; Narayanamoorthy 2007; Wemyss 2010, [16]Rogers et al. 1997, [17]Ibid. [18]Styles and Burt 1999, [19]Radstake and van Steenbergen 2013, [20]Seckler 1997, [21]Styles and Burt 1999, [22]Hanson et al. 2000, [23]Humphreys et al. 2005, [24]Radstake and van Steenbergen 2013

Climate change

- Groundwater pumping for irrigation in India accounts for an estimated 16-25 million metric tonnes yearly of carbon emissions, 4-6% of India's total. Using water-saving technologies like drip irrigation saves energy use and reduces carbon emissions substantially.[25]

Costs and benefits

- Sprinkler and drip irrigation, because of their high capital investment per hectare, are mostly used for high-value cash crops, such as vegetables and fruit trees.[26]
  - Drip irrigation costs for growing tomatoes (system costs, installation costs, energy costs, maintenance costs) were US$ 568/ha/year higher compared to furrow irrigation.[27]
- Drip and sprinkler irrigation methods, however, reduce overall crop production costs, as less human labor is required to guide water, as is the case in gravity-based conveyance systems.[28] Referring to an Indian National Committee on Irrigation and Drainage (INCID) study in 1994, Narayanamoorthy[29] mentions that: "benefit cost ratios for different crops suggest that investment in drip irrigation is economically viable..." The benefit-cost ratios mentioned for high value crops like grapes are high (13.35), while cost benefit ratios for more local crops, like coconuts, are lower.[30]
- The potential of large-scale irrigation systems in Asia can only be unlocked by introducing innovative practices. Mukherjee et al.[31] argue that integrating modern design principles (e.g. pressurized water delivery systems and advanced field levelling techniques) in these traditional systems is sometimes a cheaper alternative than rehabilitation on its own.

[25]Shah 2009, [26]FAO 1988, [27]Hanson et al. 2000, [28]Narayanamoorthy 2007, [29]Ibid. [30]Ibid. [31]Mukherjee et al. 2009

References

Brown, L.R., B. Halweil, 1998. "China's water shortage could shake world food security". *World Watch* 11(4), 10-16.

CA (Comprehensive Assessment of Water Management in Agriculture), 2007. *Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture*. Earthscan, London, UK/ International Water Management Institute, Colombo, Sri Lanka.

Extension, 2011. *Introduction to energy efficient irrigation*. Available online at http://www.extension.org/pages/27775/introduction-to-energy-efficient-irrigation.

FAO (Food and Agriculture Organization of the United Nations), 1988. *Irrigation water management: Irrigation methods*. Available online at http://www.fao.org/docrep/S8684E/s8684e00.htm.

Hanson, B.R., G. Fipps, E.C. Martin, 2000. *Drip irrigation of row crops: What is the state of the art?* Kansas State University. Available online at http://www.ksre.k-state.edu/sdi/Abstracts/Drip%20Irrigation%20of%20Row%20Crops.htm.

Humphreys, L., B. Fawcett, C. O'Neill, W. Muirheid, 2005. "Maize under sprinkler, drip & furrow irrigation". *IREC Farmers' Newsletter*, No. 170. Available online at http://www.irec.org.au/farmer_f/pdf_170/Maize%20under%20sprinkler,%20drip%20and%20furrow%20irrigation.pdf.

IWMI (International Water Management Institute), 2007. "Global Irrigated Area Map (GIAM) Version 2.0". Available online at http://www.iwmigiam.org/info/main/index.asp.

Lamont, W.J., M.D. Orzolek, J.K. Harper, A.R. Jarrett, G.L. Greaser, 2002. *Drip irrigation for vegetable production*. Agricultural Alternatives, Pennsylvania State University, College of Agricultural Sciences. Available online at http://agalternatives.aers.psu.edu/ Publications/DripIrrigation.pdf.

Narayanamoorthy, A., 2007. *Micro-Irrigation and Electricity Consumption Linkages in Indian Agriculture: A Field Based Study*. Available online at http://www.iwmi.cgiar.org/EWMA/files/papers/Drip-energy-AN-paper%20(2).pdf.

Radstake, F., F. van Steenbergen, 2013. *Shanxi Farmers Embrace Modern Irrigation Methods to Adapt to Climate Change*. ADB Knowledge Showcases, Issue 45.

Reinders, F.B., 2006. "Micro-irrigation: World Overview on Technology and Utilization". Keynote address at the opening of the 7th International Micro-Irrigation Congress in Kuala Lumpur, Malaysia. Available online at http://www.icid.org/nletter/micro_nl2006_4.pdf.

Rogers, D.H., F.R. Lamm, M. Alam, T.P. Trooien, G.A. Clark, P.L. Barnes, K. Mankin, 1997. "Efficiencies and water losses of irrigation systems". *Irrigation Management Series*. Available online at http://longbeach.wsu.edu/cranberries/documents/efficienciesandwaterlossesofirrigationsystems.pdf.

Seckler, D., 1997. *The New Era of Water Resources Management: From "Dry" to "Wet" Water Savings*. Available online at http://www.worldbank.org/html/cgiar/publications/issues/issues8.pdf.

Shah, T., 2009. "Climate Change and Groundwater: India's opportunities for mitigation and adaptation". *Environ. Res. Lett.* 4 035005 (13pp). IOP Publishing.

Shah, T., C. Scott, A. Kishore, A. Sharma, 2003. *Energy-irrigation nexus in South Asia: Improving groundwater conservation and power sector viability*. Research Report 70. International Water Management Institute, Colombo, Sri Lanka.

Siebert, S., P. Doll, S. Feick, J. Hoogeveen, J.-M. Faurès, K. Frenken, 2005. *The Global Map of Irrigation Areas*. FAO/Universitat Frankfurt am Main. Available online at http://www.lap.uni-bonn.de/research/downloads/gmia/poster_gmia4_lowres.

Styles, S.W., C.M. Burt, 1999. Evaluation of subsurface drip irrigation on peppers. Available online at http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1084&context=bae_fac&sei-redir=1&referer= http%3A%2F%2Fwww.google.nl%2Furl%3Fsa%3Dt%26rct%3Dj%26q%3Devaluation%2520of%2520subsurface %2520drip%2520irrigation%2520on%2520peppers%3D0CC8QFjAA%26url %3Dhttp%253A%252F %252Fdigitalcommons.calpoly.edu%252F cgi%252F viewcontent.cgi%253Farticle%253D1084%2526context%253Dbae_fac%26ei%3D_rekUZOYHKLg7Qa3s YD4BQ%26usg%3DAFQjCNHd0uUB1eyWn-fz3ZRvS0Va_KCKWw%26sig2%3DT4o325FUbdrBiuJp_ANgbg %26bvm%3Dbv.47008514%2Cd.ZGU#search =%22evaluation%20subsurface %20drip%20irrigation%20peppers%22

SWMRG (Soil Water Management Research Group), 2005. *Experiences with Micro Agricultural Water Management Technologies: Tanzania*. Sokoine University of Agriculture. Available online at http://www.sarpn.org/documents/d0002066/Tanzania_AWM_Report.pdf.

USDA (United States Department of Agriculture), 2011. "Online energy self-assessment tool". Available online at http://www.ruralenergy.wisc.edu/conservation/irrigation/prequalify_irrigation.aspx.

Wemyss, J., 2010. *Energy-Water-Agriculture Nexus*.