Subsurface Drip Irrigation: A Promising Solution for Maximizing Crop Yields and Water Efficiency

Abstract

One of the primary finite input resources for crop production in the upcoming decades for sustained food production will be irrigation water. On the other hand, there is a concern about the availability of irrigation water and its environmental and ecological sustainability. Urban activities, which are the primary sector, compete with agriculture for water as the global economy grows daily. As a result, it begs the question of whether the sameamount of water utilized in irrigated agriculture can continue. It is estimated that the global population will be about 9 billion to 10 billion by 2050, and more water will be thus needed (FAO, 2021; Cheng *et al*., 2021). Today, irrigation is the largest single consumer on the earth. Competition for water from other sectors will force irrigation to operate under water scarcity. To meet the twin challenges of conserving water and increasing the food supply, irrigated agriculture will have to improve water productivity, e.g. “more crop per drop”. The subsurface drip irrigation SDI could bean alternative to drip irrigation, whichuses less water. It could save up to 25% - 50% of water regarding surface irrigation.

Keywords: irrigation, crop production, ecological sustainability, groundwater

Introduction

Water status in the world and India:

In fact, underground water supplies are necessary for over 50% of the metropolitan population on the planet. More and more aquifers are being contaminated, overused, and dried up by humans, sometimes with terrible consequences. According to Margaret and Van der Gun (2013), groundwater supplies 49% of the water extracted for residential consumption by the worldwide population and around 25% of the water withdrawn for irrigation, which supplies 38% of the world's irrigated area (Siebert *et al.,* 2013). The 2030 Agenda relies heavily on groundwater. Hence, proper groundwater expertise and local hydrogeological understanding are necessary for its successful implementation (Velis et al., 2017; IAH, 2017). The three nations with the most land under irrigation are China (73 Mha), India (70 Mha), and the United States (27Mha), with an estimated 251 km3 of groundwater being extracted annually, India is the world's largest user, and 85% of that water is used for cultivation. China, India, Iran, Pakistan, and the USA make up the majority of the unsustainable water footprint, which is around 70%. Food and fodder crops accounted for 90% of the overall unsustainable water footprint, whereas crops used for fibre, rubber, and tobacco accounted for 10%. (Mekonnen and Gerbens-Leenes, 2020). Groundwater development in India has been fueled mainly by rural electrification (Smith &Urpelainen, 2016).

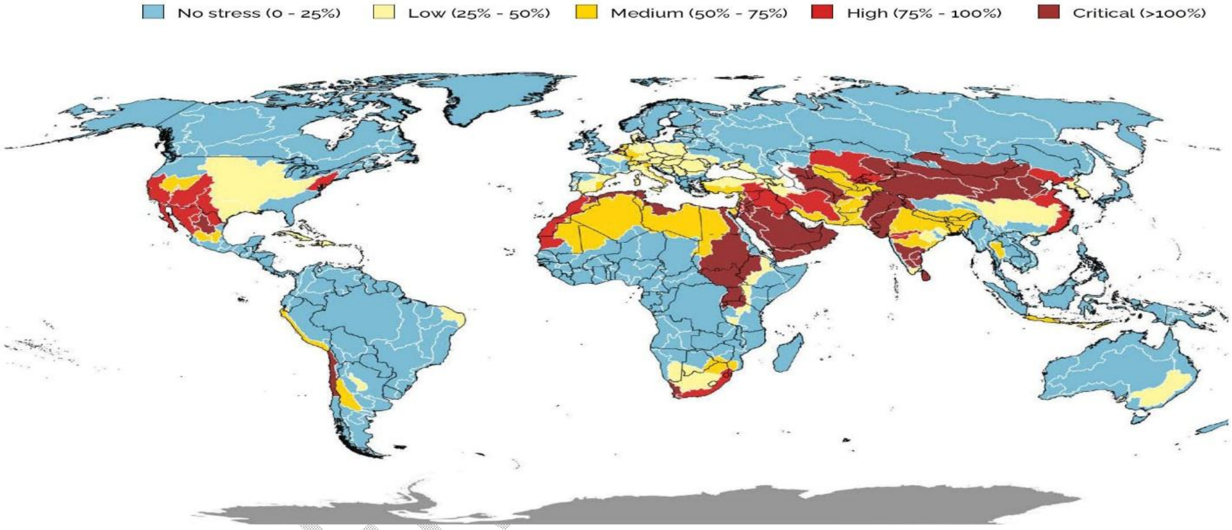

Fig.1 Water-starved status of the world (Source: FAO 2021)

Water-starved status

Water stress levels are close to or above 100% in nearly all of the Middle East and North African nations, with Kuwait, the United Arab Emirates, and Saudi Arabia having the highest percentages (fig.1). In the middle of the 1980s, the Middle East region started to produce enough food grains to meet the majority of its needs. It was ready to start exporting considerable amounts of wheat to international markets (Allan, 1997). The nation used a lot of its fossil water to cultivate crops until the early 1990s (Allan, 1999). As a result, the Middle East is the first area in the world to run out of water because of the indiscriminate exploitation of fossil water,which isnon-renewable. Now, these Middle Eastern and North African regions have been importing 40 ×106 Mg of cereals and flour annually, whichreveals that more virtual water flows into the region each year. According to estimates, the Middle East imported around 25% of their virtual water needs. By 2050, it is likely that countries like India, where the population is growing at an unprecedented rate, will not have enough water.The water requirement in India by 2050 will be in the order of 1450 km^3, which is significantly higher than the estimated water resources of 1122 km^3 per year. Therefore, to meet the shortfall requirement, it is necessary to harness an additional 950 km^3 per year over the present availability of 500 km^3 per year (Gupta & Deshpande, 2004)

Status of Groundwater and Energy in India

India is the world's largest user of groundwater. It has an annual draft of around 251 km^3, 89% of which is used for irrigation (Figure. 2), withdrawn through an estimated 20 million wells and tubewells. An estimated 60% of the irrigated area in India is served by groundwater (Shah, 2009). Groundwater-led irrigation was instrumental in the success of the Green Revolution in India in the 1960s. However, it has become apparent that gains in irrigated agricultural production have progressively led to a significant decline in groundwater levels in parts of the country, particularly in northwestern and peninsular southern India (Shah, 2009).

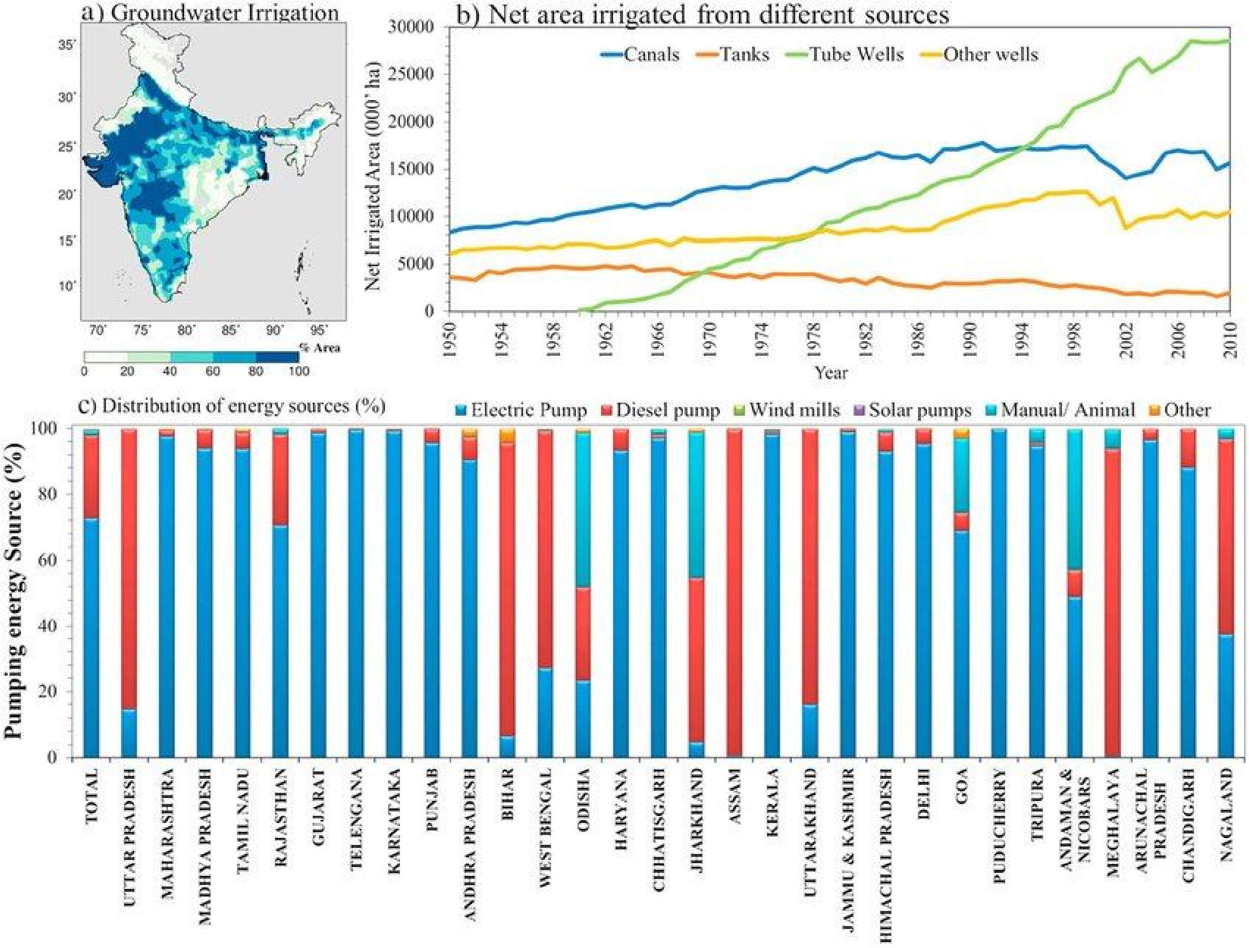

Fig. 2 Groundwater and energy use from different sources in India (Mishra *et al.*, 2018)

Currently, India's water crisis can be traced mainly to the expansion of groundwater irrigation, a trajectory set on course by India's food and electricity policy since the late 1970s. The food policy guaranteeing cheap food to consumers dictates the need to keep input prices low, including the level of electricity tariffs for pumping groundwater. Reduced electricity tariffs or free electricity to agriculture, as exist in many Indian states, coupled with assured state or government procurement of crops, encourage farmers to grow water-intensive crops, such as sugarcane, in semi-arid regions with low natural recharge. This is responsible for unprecedented groundwater depletion in large parts of India (Mukherji, 2020). Groundwater overwithdrawal in India can be traced to a lack of coherence between water, energy and food policies. Hence, solutions to India's groundwater problems should be positioned within the broader water–energy–food nexus context (Shah *et al*., 2012). Indirect management of groundwater through electricity policies has been attempted in many states in India. This has ranged from metering agricultural electricity connections and charging farmers near-commercial rates for irrigation, e.g. in the state of West Bengal (Mukherji *et al*., 2009), to rationing electricity to farmers to a limited number of hours in a day, made possible by bifurcation of electric feeders into agricultural and domestic feeders, e.g. in the states of Gujarat, Karnataka and Punjab (Shah *et al.*, 2008; Mukherji, 2017). Both these measures, the pricing and the rationing of electricity, are meant to reduce demand for groundwater by giving price and scarcity signals, respectively (Sidhu *et al*., 2020). More recently, concerns about high carbon emissions from India's groundwater pumping and the mounting subsidy burden on the electricity utilities have led to pilots of Solar-Powered Irrigation Systems (SPIS). Grid-connected SPIS are being promoted to incentivise farmers to pump less groundwater while selling electricity back to the grid rather than using it for pumping groundwater (Shah *et al*., 2018). However, evidence of whether grid-connected SPIS actually reduce groundwater pumping is still not available. Estimates of greenhouse gas emissions from groundwater pumping relative to the total national emissions from energy use range from 0.5% in China (Wang *et al*., 2012) and 3.6 % in Mexico (Scott, 2013) to 8–11% in India (Rajan *et al*., 2020). Compounding the situation, methane embedded in deep anoxic groundwater, released as groundwater is pumped to the surface, may also add to this budget (Kulongoski & McMahon, 2019).Nearly 40% of water demand in urban India is met by groundwater. As a result, groundwater tables in most cities are falling at an alarming rate of 2-3 meters per year. As per the OECD Environmental Outlook 2050, India will face severe water constraints by 2050. Indian agriculture accounts for 90% of water use due to fast-track groundwater depletion and poor irrigation systems. A dearth of storage procedures, lack of adequate infrastructure, and inappropriate water management have created a situation where only 18-20% of the water is actually used. Globally, about 40% of irrigation water is supplied from groundwater and in India, it is expected to be over 50%(Aeschbach-Hertig & Gleeson, 2012). In India, groundwater irrigation covers more than half of the total irrigated area (around 42 million ha). Agriculture is the largest single user of water, with 65–75% of freshwater currently used for irrigation (Bennett, 2000; Prathapar, 2000). In some cases, it draws as much as 90% of the total water (Allan, 1997).

Agriculture Water useSector-wise in the World:

Irrigated agriculture still accounts for 70% of freshwater withdrawals (Fig. 3). Use for food processing is also significant, up to 5% of global water use (Fig. 3). Subsurface drip facilitates the use of degraded quality water (Palacios-Díaz *et al*., 2009;Boretti & Rosa, 2019), by increasing irrigation frequency thus minimising the matric and osmotic stress, and in cases of treated wastewater reducing pathogen movement, odours, and animal and human contact.

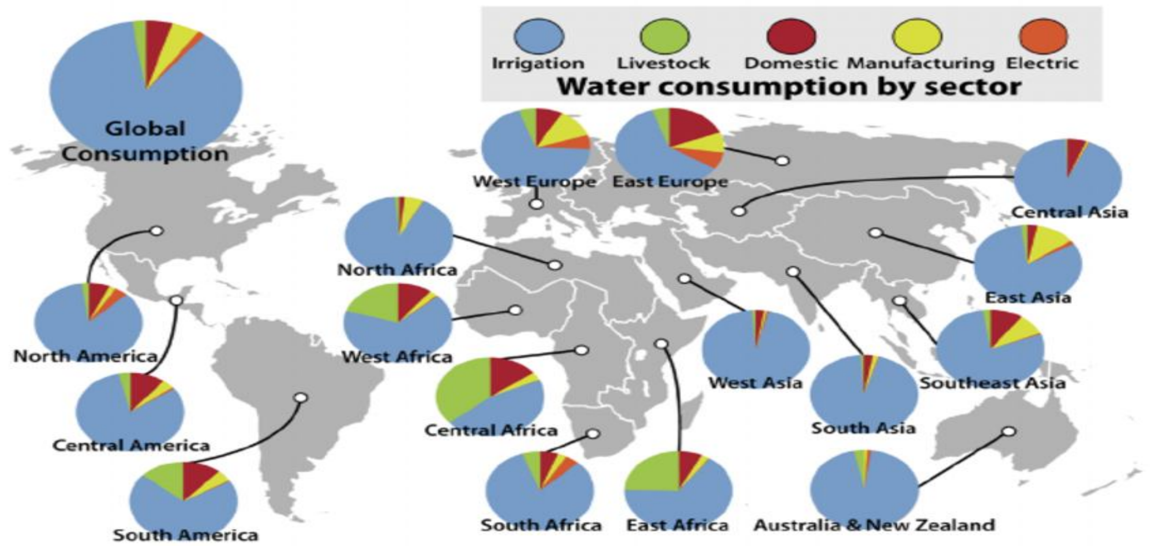

Fig.3 Sector-wise water use in the world

Subsurface Drip irrigation

The application of water below the soil's surface using microirrigation emitters is known as SDI. Typically, the emitters' discharge rate is less than 7.5 L/h (ASAE, 2001). The irrigation network system in the plough layer directly flows water and liquid fertiliser into the root zone for the growth of crops. SDI might be a significant factor in improving irrigation water use efficiency (IWUE). Although SDI has been widely employed in agricultural production as an effective water-saving irrigation technique, its effects on crop yield, irrigation water productivity (IWP), and water productivity (WP) depend on the management of the field, the climate, and the characteristics of the soil.SDI is a water conservation technique that exposes crops to a particular level of water stress during a specific developmental phase or throughout the entire growing season without a significant reduction in yield. The use of a pressurised irrigation system that applies water below the soil surface at a slight operational pressure and minimises soil evaporation has been famous for saving water and improving IWUE (Ayars *et al*., 2015).

In comparison to other forms of irrigation, SDI reduces water loss through evaporation, runoff, and deep percolation. As a result, the irrigation water that was saved may be used in other areas. In addition, it increases crop yields by maintaining a consistent level of soil moisture throughout the crop's effective root zone. As there is no direct irrigation water interaction with the human operating system in SDI, treated wastewater can be used with little risk to human and animal health. We can choose SDI in peri-urban locations where there is a lot of potential for utilising treated wastewater. Also, because agrochemicals are appliedprecisely using the SDI system, the amount applied decreases. SDI is a technology for climate-smart agriculture. Due to smaller intake heads, the SDI operating system uses less energy than traditional irrigation techniques. Therefore, in addition to increasing energy efficiency, SDI may also stop the anaerobic degradation of plant materials, significantly reducing methane gas emissions.

Brief history of subsurface drip irrigation

China is the pioneer in using SDI, where clay vessels were buried in the soil and filled with water. The water moved slowly across the soil, wetting the plants' roots (Bainbridge, 2001). The modern SDI system as we know it nowadays developed around 1959 in the United States (Vaziri & Gibson, 1972; Camp et al., 2000), especially in California and Hawaii drip irrigation variants. SDI laterals consisted of polyethylene or polyvinyl chlorideplastic pipes with punched holes or with punched emitters. Initially, SDI systems often had the problem of emitter clogging, root intrusion, rodent damage, and poor uniformity.

As per recent estimates,during the past 50 years of intensive irrigation, approximately 50 % of the water initially present in the aquifer has been depleted. The result is that many areas are running short of water. Farmers have, therefore, been forced to switch from conventional irrigation to water-saving irrigation methods such as low-energy precision application (LEPA), sprinkler irrigation, and subsurface drip irrigation.

Design and installation

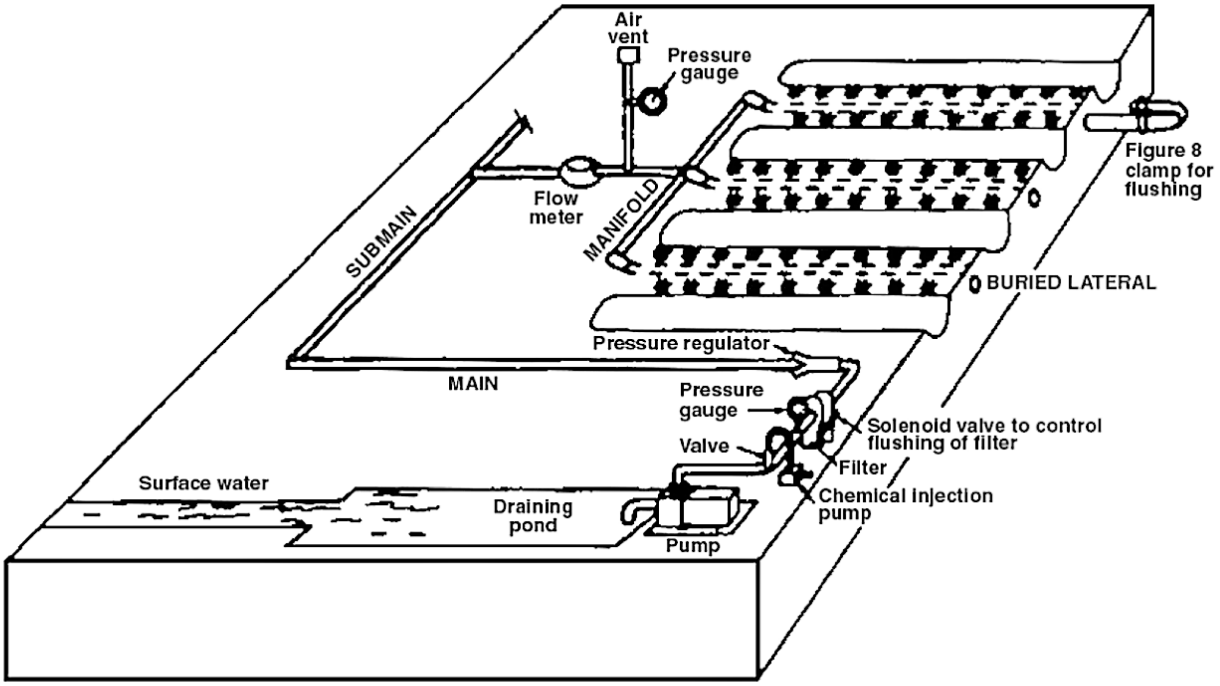

Fig.4 Design and installation of Subsurface drip irrigation

The main components of SDI comprise the main supply tube (Lateral drip lines), submains laterals and emitters(fig.4)

- *Lateral drip line*

Tapes and tubes are used as laterals. Generally, tube wall thickness ranging from 0.4 mm to 1.5 mm (Hanson *et al.*, 2000) is commonly used in SDI. There are two classes of tape wall thickness. Flexible Thinwalled (0.15 mm to 0.30 mm) which are used for shallow installation, whereas thicker-walled (0.38 mm to 0.50 mm) tapes are installed deeperwhere the soil does not provide sufficient support to prevent collapse by equipment or soil weight (Camp *et al.*, 2000).

- *Tape installation depth*

The tape depth is often decided by the crop, soil climate characteristics and anticipated cultural practices, but it generally ranges from 20 to 70 cm depth. In shallow systems, relatively deeper installation should reduce soil evaporation and also allow for a broader range of cultural practices. However, deeper installation may limit the effectiveness of the SDI system for seed germination/ crop establishment.Deeply placed drip lines may require an excessive amount of irrigation for germination/ crop establishment due to uneven distribution of water. It reduces the WUE. Deeper placement may restrict the availability of subsurface-applied nutrients and chemicals (Camp and Lamm, 2003).

- *Lateral spacing*

The lateral spacing of 0.25 to 5 m is commonly practised in SDI, as determined by crop behaviour, cultural practices, soil, and properties. Wider lateral spacing is practised in heavy-textured soil. Closer spacing is recommended for sandy soil (Phene& Sanders, 1976). Lateral spacing of 2 m intervals on a 1:2 drip tape: crop row has shown successful results in cotton (Raine *et al.*, 2000).

- *Installation*

The first and foremost step in installing a successful SDI system is adapting a proper hydraulic design to ease the flow ofwater through a hydraulic gradient. This facilitates the system in overcoming the frictions related to soil characteristics, field size, shape, topography, and water supply. Lateral diameter and length influence water application uniformity (Kang *et al.*, 1999). Lamont*et al.* (2002) found thata tape diameter of 125-200 mm was the industry standard and typical for subsurface drip irrigation, whereas the length of laterals ranged from 90 m to 180 m.

- *Emitters*

Widely spaced crops such as vines, ornamentals, shrubs, and trees were used as line source emitters. Point source emitters are used for small fruits, vegetables and closely spaced row crops. The emitters used for SDI are much the same as those used for surface drip, but the emitter is fixed internally in the drip line (Harris, 2005).SDI systems generally consist of emitters that have discharge rates of less than 8 L/hr (ASAE, 2001).

- *Emitter spacing*

Emitter spacing should generally be less than the drip lateral spacing,and it mainly depends on the spacing of crops (Lamm & Camp, 2007).

- *Flushing capacity*

Flushing capacity is the major component of an SDI system that decides its performance. Many SDI systems appear to have been installed with inadequate flushing capacity, resulting in sediment deposition, decreases in flow volumes, and blockages (Pitts *et al.*, 1996). This will produce higher backpressures in the mains, which may also affect system performance (Lamm & Camp, 2007). Retrofitting large valves or increasing the number of valves may solve some flushing problems (Raine *et al.*, 2000).

- *Soil wetting pattern*

SDI's wetting pattern can be affected by irrigation management and SDI design aspects such as emitter spacing and drip line depth. The dripper function can also be modified after installation. In one study, the heterogeneity of the soil near a subsurface emitter that had been disturbed by farm equipment resulted in low emitter flow (Shaviv& Sinai, 2004).

SDI and its prospective in crop management and cropping systems

The SDI provides solutions for a variety of issues, including poor WUE, declining water quality, lower risk of aquifer pollution due to reduced deep percolation of fertilisers and other chemical compounds, and improved yields. The ability to supply water and nutrients to the most active area of the root zone, protect drip lines from damage caused by cultural techniques, and maintain a dry soil surface for better weed control and crop health. According to recent studies, crop yields can be maximised with SDI while reducing pollution from leaching losses of N with adequate management (Thompson *et al.*, 2000). Irrigation with SDI allows the maintenance of low root-zone salinity, even when using irrigation waters containing appreciable salts (Oron *et al.*, 1999). Operating pressures are often less than in drip irrigation,thus reducing energy costs. Improvement in plant health means fewer diseases and fungal infections due to drier and less humid crop canopies. Certain types of soil fumigation can be done with this technology. Since fertiliser and pesticides are applied precisely and on time through the system, improved fertiliser and pesticide management can lead to greater efficacy and, in some cases, a reduction in their use. As the system does not have to be taken out during harvest and put back in before the second crop is planted, double cropping chances could be improved.Farming operations and management of many field operations can occur during irrigation events. Fewer field operations result in less soil compaction, and soil crusting caused by irrigation is significantly reduced. Variability in soil water regimes and redistribution is often reduced with SDI as compared to surface drip irrigation. Additionally, weather-related application constraints such as high winds, freezing temperatures, and wet soil surfaces are less critical, and the ability to irrigate during freezing conditions can be particularly beneficial when preseason irrigation is used to increase seasonal irrigation capacity effectively.

Shortfalls in SDI

The significant shortcomings of SDI are its high initial cost and the potential for the development of soil salinity. Conversion from conventional irrigation systems to SDI requires high capital inputs and an increase in time required for irrigation design implementation and management. Soil salinity problem is quite often associated with SDI. Even though there is an advantage of Preciseapplication of water and nutrientsto the effective root zone, the upward flow of water from the SDI emitter to the surface and loss of waterby evaporation and transpiration can lead to high soluble saltconcentration in the soil surface(Dasburg and Or 1999) however, itcan be overcomeby the use of sprinklers which further increases thelabour and capital inputs(Hillel,2000).The problem of salt accumulation is more common in arid and semi-arid regionswhere there is a deficit in rainfall to leach out the salt below the root zone. Specialised tillage methods and planting salt-tolerant crops can help minimise salinity problems with SDI (Roberts *et al.*, 2008).Drip lines should be monitored regularly for root intrusion; system operational and design procedures must employ safeguards to limit or prevent further intrusion. Certain perennial crops' roots may encroach on drip systems and prevent water flow reduction. In order to prevent accumulations of silt and other precipitates in the laterals, drip lines must be flushed periodically. Similar to previous systems, SDI needs more operational management. Depending on installation depth and soil conditions, the wetting pattern of SDI will be too small in coarse-textured soils, resulting in a crop root zone that is too small and possibly limited germination. This may be especially problematic on soils with vertical cracking.

Challenges and opportunities for SDI design and installation

Creating a flexible SDI can be tricky since farmers may not be aware of their long-term agricultural plans or their farms' potential for increasing cropping intensity. Destruction of laterals by field equipment and machinery and damage to drip lines by rodents and other animals are also significant challenges in SDI. However, these issues can be resolved by using a GPS guiding system. (Sorensen, 2019). Although they add complexity and raise initial expenses, automated monitoring and control systems and agrochemical injection systems can be profitable in the long run. Many SDI system designs that are solely based on crop requirements will not be able to perform in a variety of conditions. This need for flexibility is also a significant driver for the creation of reliable monitoring and control systems that can evaluate the status of plants and soil water and make adjustments as needed. Installation of a smaller SDI system can aid in obtaining expertise in SDI management and operation; nevertheless, this strategy may not result in the successful adoption of SDI because farmers with little free time may be unwilling to invest the time required to master a tiny system.

Advancements in technologies such as sensor data collection, management, and analysis, with the assistance of IOT (Internet of Things), models, and automation systems in SDI, will help develop robust systems and monitoring strategies that could help overcomethis impediment. Improved characterisation of the soil water content (in two and three dimensions) with better soil water sensors and modelling could help irrigation managers apply water at the right place and at the right time. The continued search for more sustainable irrigation systems provides opportunities for SDI as an efficient delivery method with greater uniformity of crop production. Additional environmental benefits of SDI will likely include a reduction in GHG emissions. These combined environmental benefits may become an essential reason for SDI adoption in the near future among major farming communities.

Performance of different crops as influenced by SDI system

SDI can help in improving the crop yields, quality and water use efficiency of the crops; earlier findings revealed that growing crops under the SDI system was found to be better than the conventional irrigation system in various vegetable, field and perennial crops, which were briefly reviewed below

Yield, Water saving, IWUE under SDI system

Phene*et al*. (1987) demonstrated significant yield increases in tomatoes with the use of high-frequency SDI and precise fertility management. Enciso *et al*. (2015) found that the total onion yield obtained with the SDI systems was more than 93% higher than the yield obtained with furrow irrigation systems due to SDI allowing for more frequent and smaller irrigation depths with higher irrigation efficiency than furrow irrigation systems.Sidhu *et al.*(2020)confirmed that in rice-wheat cropping systems under conservation agriculture,irrigation use efficiency obtained with the SDI system ranged from 17.5 to 25.2 kg/ m^3 and from 4.2 kg /m^3 to 6.2 kg /m^3 in floodirrigation for riceand wheat. However, grain yield and irrigation water input in rice and wheat were generally similar under different SDI treatments and conservation agriculture. Irrigation water savings were 48–53% in rice and 42–53% in wheat under a combination of SDI and conservation agriculture compared to flood irrigation systems. Both rice and wheat needed 20% less N fertiliser under the SDI system to obtain grain yields similar to that under flood-irrigated crops.Cui *et al.* (2008) pointed out that SDI can improve IWUE by 26.7–46.4% and the fruit quality of grapes without detrimental effect on the fruit yield in arid regions. The results demonstrated that the minimum amount of water, along with the highest use efficiency, is delivered through SDI and Surface drip irrigation, respectively. SDI achieved higher tomato crop yields as compared to surface drip irrigation in sandy soil (Del Amor & del Amor, 2007). Al-Omran *et al.* (2010) concluded that SDI increased the IWUE and yield of their tomato crop by producing a good moisture distribution in the root zone, leading to the conservation of irrigation water. Three irrigation strategies: 1.0 of the entire irrigation supply (T1), 0.8 of the total irrigation supply (T2) and 0.6 of the entire irrigation supply (T3). The results showed that the highest yields were found in the plots irrigated by subsurface drip irrigation at T1 (94.1 t/ha) and T2 (81.4 t/ha). Conversely, the fully stressed treatment (T3) reduced the amount of irrigation water by 40% but significantly decreased mean tomato yield by 25.6% and 26.1% under subsurface and surface drip irrigation, respectively, as compared to T1.The maximum IWUE tended to be higher for subsurface drip than for surface drip irrigation systems. The greatest IWUEs were obtained from subsurface drip and surface drip at T3 (19.7 kg/m^3 and 18.3 kg/m^3), whereas the lowest IWUEs were those estimated in T1 (15.9 kg/m^3 and 14.8 kg/m^3, respectively). Jose *et al.*(2008) opinedthat based on field experiments conducted under the SDI systemfor irrigation scheduling incorn a, good relationships obtained in the study between crop performance indicators and seasonal ETc demonstrate that accurate estimates of ETc on a daily and seasonal basis can be valuable for making tactical in-season irrigation management decisions and for strategic irrigation planning and management under SDI system that willhelp in saving water.

Table1. Performance of SDI under different crops and cropping systems in different regions ofthe world

Sl.no	Country	Crop	Yield increase (%)	Water use efficiency	Water saving	References
1	Spain	Olive	30 % compared to drip irrigation	7.75 kg/m^3 compared to drip irrigation, 6.75 kg/m^3	8-10 % compared with drip	J. Martínez and J. Reca 2014
2.	Australia	Corn	37% increase in yield	23.5 %	25%	Jose *et al.*(2008)
3	USA	Maize	35-40 % increase in yield compared to rainfed	0.8-3.1 kg/m^3 increase	25 % water saving	Irmak*etal.*(2016)
4	USA	onion	93% higher yield than furrow irrigation	10 kg/m^3 over Furrow irrigation	44 % water saving	Enciso *et al.* (2015)
5	China	Wheat	10 % increase in yield over surface irrigation	4.50 kg/m^3 over surface irrigation	26% water saving	Umair *et al.*(2019)
6	India	Rice	8-10 % higher yield over drip irrigation	1.20 kg/m^3 over drip irrigation	10-15 % water saving	Rajwade *et al.*(2014)
7	India	Paddy	10-15 % decrease in yield over flooding	2.0 Kg/ha mm Over flooding	40-45 % water saving	Rana*etal.*(2022)
8	India	Soybean, Chickpea Pumpkin	15-43 % over control	2-16 % increase in WUE	-	Bhattari*et al.*(2008)
9	Saudi Arabia	Potato	15-25 % over drip irrigation	1-2 kg/m^3 over drip irrigation	10-20% water saving	Mattar *et al.*(2021)

Modelling, Sensors and Automation in SDI

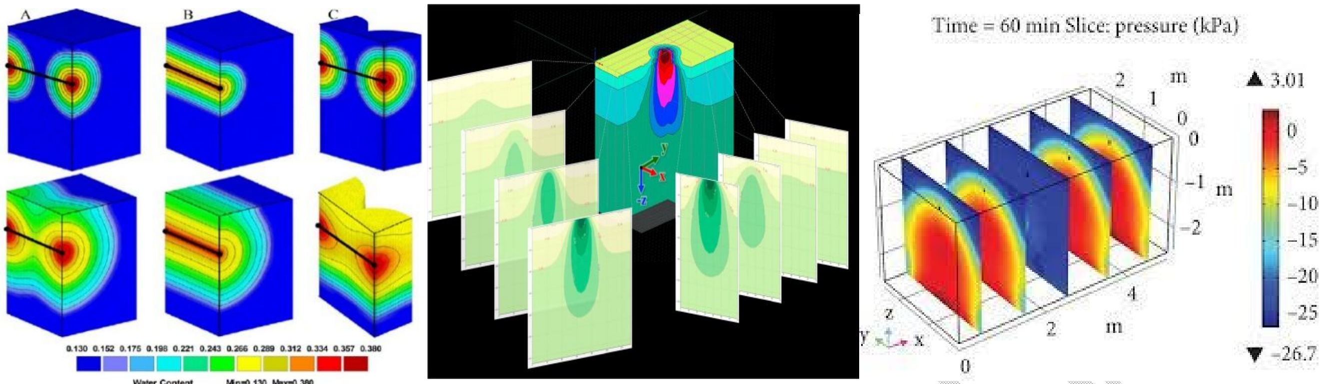

Fig 5Illustrative examples of simulation modelling under SDI for wetting volume depth of emitters (Kandelous*et al.*, 2011)

The knowledge of both the horizontal and vertical dimensions of the soil volume to wet, where the roots are located, and the initial soil water content allows one to evaluate the duration of irrigation; in addition, when the SDI plant has to be designed, the horizontal dimension of the wetted volume also permits the evaluation of emitter spacing (Provenzano, 2007). The use of simulation modelling techniques will also help in understanding the processes of hydrolysis, nitrification, mineralisation, and ammonium adsorption in cropping systems that will save the resource inputs in crop production (Eltarabily*et al.*, 2019).Simulation studies conducted by Arbatet *al.*(2020) using the HYDRUS-2D modelshow that a dripline depth of 0.15 m combined with one or two daily irrigation events maximised water extraction and reduced percolation in rice. Moreover, simulations with HYDRUS-2D could be helpfulin determining the most appropriate location for soil water probes to manage the SDI in rice efficiently.A fully automated sensor-based subsurface irrigation system for the Ratoon crops reduces water usage(40%). It increases the cycle of the Ratoon crop with the minimum maintenance cost of the irrigation system (Krisnhapriya*et al.*, 2017). SDI has also influenced canopy temperature and spectral reflectance of crop canopy since water is available uniformly throughout the crop growth period. The spectral reflectance ofcotton was significantly influenced under SDI (Attia *et al.*,2015). The use of Hydrus 2 D Models under a based conservation agriculture (CA) system could simulate the daily changes in profile soil water content with reasonable accuracy. It can simulate soil water balance, indicating higher cumulative root water uptake, lower cumulative evaporation, and higher soil water retention. This helps save irrigation water by saving deep percolation losses andreducing irrigation frequency(Patra *et al.*, 2021).

Tillage Management Practices and SDI

Combiningagronomic innovations like CA with SDI and fertigation may be a sustainable option to deal with the emerging troubles of water scarcity and declining groundwater desks (Patra *et al.*, 2021). There is a significant capability for water savings in CA by minimising the deep drainage and evaporation losses and probably diverting the soil moisture used for the consumptive use of crops. CA, coupled with SDI, is a better choice for irrigation water saving, soil moisture conservation, precision irrigation and nutrient management. Besides the reduction in denitrification and volatilisation losses through fertigation, the use of SDI in CA may even help lower global warming potential in the long run.

Effect of depth of dripper lines and emitter discharge onthe performance of SDI

To maximisethe potential water savings of subsurface drip irrigation (SDI) systems, it is necessary to optimise its design and irrigation management, highlighting the depth of emitters and frequency of irrigation.The depth of dripper lines also plays a significant role in crop performance under SDI.Hutmacher *et al.* (1996) demonstrated yield increases in alfalfa production using SDI systems buried at depths of 0.7 m.Dukes *et al.* (2004) noticed that in sweet corn-peanut rotation under an automated SDI system, laterals buried at a depth of 23 cm performed better in terms of both the crop yield as compared to laterals buried at a depth of 33 cm in sandy soils due to deep percolation of irrigation water under SDI.

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