Proc S Afr Sug Technol Ass (2022) 94 : 136-141

SHORT COMMUNICATION

SYNERGISTIC SUSTAINABLE SURFACE IRRIGATION AND DRAINAGE: PILOT PROJECT

Lecler NL[1,2]

[1] *Dr NL Lecler Consulting Services, now at Illovo Sugar Africa*
[2] *Honorary Associate Professor, School of Engineering, University of KwaZulu-Natal, Durban, 4041*

Lecler.support@gmail.com or nlecler@illovo.co.za

Abstract

An ideal irrigation system should permit low-loss, highly-uniform applications of water to prevent undesirable crop stress, and require minimal energy and effort to operate. Any surface and sub-surface drainage issues should be addressed to ensure that productivity does not decline due to the development of salinity and/or water-table issues. The layout of the system should permit efficient machine operations with minimal compaction, and precision fertigation. The maintenance should be simple, and the overall life-cycle costs, relatively low.

Synergistic Sustainable Surface Irrigation and Drainage (SSSID) is a new type of short-furrow surface irrigation that is integrated with drainage. It is being developed to meet the criteria of an ideal irrigation system. Although well-supported by scientific rationale and research results, SSSID is new and not yet fully commercialised. Given this context, RCL Foods and the Water Research Commission, supported the installation of a pilot SSSID system for a seedcane scheme.

The design and installation involved a unique process that incorporated the use of state-of-the-art Global Navigation Satellite System (GNSS) control technologies for land-forming and sub-surface drainage. The pilot system was very likely a world-first, and as such, numerous opportunities to improve the system were identified during the project. Nonetheless, there was strong evidence that SSSID has great potential for facilitating exceptional agricultural productivity, and outstanding water, soil and energy stewardship. Highly-uniform irrigation water applications were measured and simulated for a range of representative conditions at the site. The feedback from stakeholders was positive and excellent crop yields were attained, despite the excessive application of wastewater following a fire incident at the mill. In the first block of the project, the sugarcane was harvested as seedcane when it was only approximately 10 months old, and it yielded 132 t/ha.

Keywords: energy, irrigation, drainage, world-first, environmental impacts, salinity, economics

Introduction

RCL Foods agreed to collaborate in piloting a novel Synergistic Sustainable Surface (short-furrow) Irrigation and Drainage (SSSID) system. While the motivation for SSSID is well supported by research results and financial analyses (Lecler *et al*., 2007; Mills 2009; Lecler 2016a; Lecler 2016b; Lecler and Harris, 2019), this was the first time that a system, integrated with near-optimal surface and sub-surface drainage and automation, had been installed on a commercial scale. RCL Foods required the system to use wastewater from a sugar mill. Apparently, this had not been done successfully by using drip, sprinkler and centre-pivot systems. Due to the novelty and potential of the SSSID system and the installation process, funds from the Water Research Commission Water Technologies Demonstration Programme (WADER) were used to subsidise the installation costs. This paper contains a brief description of the SSSID system, the design and the installation processes, and results from an initial performance assessment.

SSSID Concepts

SSSID is a novel type of short-furrow irrigation, where water is supplied to sets of emitters via a network of buried pipes. Control valves are operated in sequence, so that the emitters discharge water into sets of short, blocked furrows; typically, a set could consist of 50 to 60 furrows that are 30 m to 40 m long. The furrows are laid out on a land surface that is specially shaped to permit good surface drainage (i.e. with no ponding) and excellent furrow irrigation performance.

Short, blocked furrows are a key component of the system, because on many soils and for a relatively wide range of slopes, short, blocked furrows facilitate excellent irrigation performance i.e. small amounts of water can be applied with great flexibility, evenness and minimal losses. An important innovation of the system is that, although the furrows are short, the buried pipe layout and the manual or automatic sequencing of the furrow sets (by means of control valves), facilitate long fields and machine runs, which leads to the efficient mechanisation of farming operations. Furthermore, the pressure at the emitters is ultra-low, i.e. approximately 2 m to 2.5 m.

The ultra-low-pressure requirements can lead to major energy savings, compared to alternative pressurised irrigation systems. For example, the filters used in many drip systems require a pressure of 20 m to flush. Thus, drip irrigation, which is already considered to be a low-energy option, can require close to 90% more energy than SSSID. Sub-surface drains are integral to the SSSID system. They help to protect against the insidious development of a high-water table and/or saline soils, which have led to land degradation and decreased productivity on massive areas of irrigated land in the world. The sub-surface drains are also connected to the laterals by means of valves, so the laterals can be flushed into the drains to help remove any potential emitter blockages.

Design and Installation

The design and installation process included the following:

- field work, to gather data from representative 'test furrows'. The data were used with a computer simulation model to determine a range of suitable land-forming and short-furrow irrigation design parameters;
- a high-resolution topographical survey;
- the design of a near-optimum landform to give good surface drainage and a robust short-furrow irrigation performance, with minimal disturbance of the topsoil;
- the hydraulic design of the irrigation pipe network;
- GNSS-guided land-forming and the installation of sub-surface drainage pipes;
- marking out the system, trenching and installing the pipes and specially-constructed fittings in the field;
- installing the components needed for automation and control by means of a cell phone;
- bed-and-furrow formation;
- the initial 'bedding-down' irrigation operations; and
- planting, by using a double-disc, whole-stick sugarcane planter.

Results

The initial performance assessment was based on:

- measuring the pressures along the irrigation laterals – a minimum variation would ensure a uniform flow of water into the short furrow sets;
- the use of data gathered during in-field furrow tests, together with computer simulations, to determine if the short, blocked furrows would allow for the relatively even distribution of infiltrated water for the range of slopes and soil conditions at the site;
- feedback from an independent technical evaluation and from stakeholders who attended a Field Day; and
- the yield of the crop harvested for seedcane, after only 10 months.

Pressure variation

The pressure between emitters that was measured near the start, middle and end of numerous laterals during commissioning, was minimal and within the irrigation design standards, which allows for a 20% variation (SABI, 2021).

Furrow performance

At a design emitter flowrate of 18 l/min, the time for the advance front to reach the end of consolidated furrows could range from as little as 12 minutes on the steeper-sloped (1:374), 40 m long furrows, in relatively wet conditions, with the recession time taking close to six hours, to as long as 65 minutes on the flatter-sloped (1:2000) furrows, in relatively dry conditions, with the recession only taking two hours. According to computer simulations, the associated low quarter distribution uniformities (DU_{lq}; Howell, 2003) were excellent, ranging from 0.78 to 0.9 for these two extremes, in terms of potential conditions, and for an average water application depth of approximately 18 mm. Thus, although the advance and recession times were very different, the infiltration depths simulated along the furrow ended up being remarkably similar, with excellent uniformity. This is a huge performance benefit of short, blocked furrows and one of the main distinguishing features of SSSID.

Only approximately 7% of the soil surface was wetted during irrigation, thus minimising the losses due to evaporation from a wet soil surface. The area wetted was also between the cane rows and was shaded relatively quickly after early canopy development. The small, but frequent, low-loss water applications, facilitate efficient irrigation and minimal crop stress, even in shallow soils. With a crop using, say, 6 mm of water per day, the system would allow 18 mm to be applied every three days.

Multiple simulations for relatively wet furrows on relatively steep slopes (1:374), and relatively dry furrows on relatively flat slopes (1:2000), which represent the two extremes of conditions likely at the site, showed how the emitter flowrate and irrigation time could also be varied substantially, with the infiltration along the length of a furrow remaining highly uniform.

Stakeholder feedback

According to a report and the responses to a questionnaire by Bremner (2022), most stakeholders were impressed with the system and gave positive and constructive feedback following the Field Day, although there was still a degree of risk aversion.

The reasons why stakeholders would consider a move to SSSID included:

- its low energy consumption;
- its relatively simple operation and maintenance once the system is installed;
- the “good” control of flows into the short furrows;

- the high tolerance to poor water quality (wastewater from a sugar mill) because it did not burn the leaves, as with the overhead sprinkler systems, or pose a high risk to blockages, as with the drip irrigation systems;
- the layout was suited to efficient machine operations and controlled trafficking;
- it was adaptable to fertigation, with few limitations as to what products can be used;
- it was adaptable to more regenerative farming systems, with more frequent replants and rotation crops; and
- SSSID addresses numerous issues that are associated with drip, pivot, sprinkler and furrow systems.

The concerns that were expressed included the following:

- it has not yet been fully proven – it is still a new technology;
- although the life-cycle costs are relatively low, the installation and land-preparation costs are high, because the surface and sub-surface drainage is incorporated upfront;
- SSSID is not suited to steep slopes or for soils with exceptionally high infiltration rates;
- there are questions as to whether the system can be upscaled to larger operations;
- there is the question of how to convince ‘old-school bosses’, who may be sceptical of new innovations;
- bed-forming requires special implements and a degree of maintenance; and
- the installation methodology, as well as some materials and automation, are still being refined.

Crop yields
The first block was harvested in March 2022, when the seedcane was approximately 10 months old, and it yielded 131.5 t/ha. Considering that the cane had been subjected to excessive amounts of wastewater from the mill, following a fire, this was an excellent result. It indicates that if the crop had been harvested commercially at around 14 months of age, it is likely to have yielded more than 180 t/ha, which is an exceptionally high yield for the Komatipoort area.

Discussion and Conclusions

For all those involved with the pilot project, there was a substantial element of ‘doing-things-for-the-first-time’, which has its risks and is seldom optimal. The installation was complex and it required the precise application of state-of-the-art technologies and engineering expertise. Some of the materials, connection arrangements, valves and fittings were not ideal and could be improved. The bed-and-furrow forming implement was novel and even the method of planting into the SSSID beds had not been used before. Many options for improvement were highlighted. The lessons learned and the experience gained will be of great value for future projects.

Despite some of its challenges, the pilot system had noteworthy performance characteristics. For example, exceptional crop yields were achieved by using wastewater, which is not ideal for use in drip, sprinkler and/or pivot systems. SSSID required only a fraction of the power that is used by the alternative pressurised irrigation systems. Data gathered in-field, observations and computer simulations indicated that irrigation water could be applied with precision, that there would be a high degree of uniformity, no spray-evaporation and wind-drift losses and that there would be minimal evaporation losses from a wetted, unshaded soil surface. The crop yield at the pilot site was excellent. All these performance characteristics facilitate high water-use productivity. Irrigation without drainage can seldom be sustained; therefore, although it is a cause for some concern among stakeholders (due to the additional costs), the integration of irrigation with drainage, intrinsic to SSSID is likely to be hugely beneficial.

Strong evidence, including an independent technical evaluation, supports the assertion that the SSSID system installed at the RCL pilot site was very likely a world-first and offers the promise of a "game-changing" and "near-ideal" irrigation and drainage solution for addressing many of the major challenges facing the irrigation industry, including the conservation and stewardship of water, soil and energy resources. Further development and piloting of SSSID is recommended and, if successful, will benefit the wider community who depend on irrigated agriculture.

References

Bremner MH (2022). *Technical evaluation of synergistic surface irrigation and drainage (SSID)*. Contract No. Po23730, Project No. P10495-009-002. Report to the Water Research Commission, South Africa, by Bosch Projects (Pty) Ltd and Bosch Capital, (Pty) Ltd, Durban, South Africa.

Howell TA (2003). Irrigation efficiency. Encyclopaedia of Water Science, Marcel Dekker, Inc. New York, United States of America.

Lecler NL, Mills DD, Hill AC and Smithers JC (2007). *Crop irrigation system. (South African Patent 2010/03121).*

Mills DD (2009). *Automated short-furrow irrigation*. Unpublished MSc Eng dissertation, School of Bioresources Engineering and Environmental Hydrology, University of KwaZulu-Natal, South Africa.

Lecler NL (2016a). A synergetic system to produce sugarcane using surface irrigation. *International Sugar Journal*, CXVIII (1413).

Lecler NL (2016b). Projects and strategies to introduce a synergetic controlled traffic farming system to Zimbabwe. Proceedings of the 26th ISSCT Congress held in Thailand, Vol 29.

Lecler NL and Harris AJ (2019). Framework and methods to assess irrigation and drainage decisions. *Proc. S. Afr. Sug. Technol. Ass.*, 92: 139-157.

SABI (2021) *SABI Agricultural Norms for the Design of Irrigation Systems*. https://www.sabi.co.za/0-pdf/SABI%20Norms%20-%20%20Agricultural-2021.pdf (last accessed 13 June 2022)

Acknowledgements

The support of each of the following entities, and the people representing them, in connection with the pilot project was very important. The author is very grateful to them all.

- The Water Research Commission Water Technologies Demonstration Programme (WADER);
- RCL Foods;
- Agri Drainage;
- Fastcon Construction;
- Agri IO; and
- Alasdair Harris, Stephan Geldenhuys and Jaro Geldenhuys, who were the main co-conspirators for SSSID, especially the 'D' (drainage) part. It was Alasdair's idea to link

the laterals to the sub-surface drains, for ease of flushing. It was Stephan and Jaro's enthusiasm, as well as their experience and expertise in drainage, GNSS machine control technologies and agriculture, in general, as well as their entrepreneurial founding of Agri Drainage, which was key to their collaboration in this project.