EVALUATING WATER SAVING USING SMART IRRIGATION AND HARVESTING SYSTEMS

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ABSTRACT
There are about 3,000 commercial irrigators in peri urban Sydney. Many of them are town water users on 2 hectare holdings. Below average rainfall over the last several years has resulted in water use restrictions introduced by the water authority, Sydney Water. The irrigators are also highly visible, resulting in intense environmental scrutiny by regulators and the general public. Consequently, NSW DPI and the University of Western Sydney received funding to evaluate two innovative technologies, the Kapillary Irrigation Sub-Surface System (KISSS) and the Irrigation Water Recycling System (IWRS) to both reduce potable water use and limit off site effects of any runoff from these peri urban farms. The main objective of the study was to better understand the concerns and issues of farmers while evaluating KISSS and IWRS under field situations for their potential to save potable water and protect the environment.

The KISSS applies water directly to the root zone of plants with a minimum of water loss through runoff, evaporation and deep drainage. In this system, water is applied below the ground surface directly to the plants roots area, resulting in a significant improvement in water application over traditional drip irrigation system. Also, since the water is applied below the surface, the water wastage due to evaporation is almost eliminated. The IWRS collects irrigation and rainwater runoff from cropped areas during sprinkler irrigation and minor rain events and stores this within the farm for reuse in the next irrigation. Overall, the IWRS is designed to improve the availability of farm's irrigation water supplies and reduce nutrient runoff from farms.

A participatory approach was adopted in this study, involving a total of eight farmers and a number of other stakeholders. An initial survey of target farmers found their ethnicity, technical knowledge, their individual perception of the water scarcity and their economic conditions to be important indicators to their commitment and motivation to test and monitor the KISSS and IWRS systems on their farms. Other issues impacting the farmers included the escalating costs of water and fertilisers, the considerable variability in profits as vegetables prices fluctuated and large time inputs required of them in marketing of produce.

Many farmers were initially reluctant to get out of their comfort zone and consider IWRS or the KISSS irrigation system over their current overhead sprinkler irrigation system despite the potential water savings and environment protection. However through demonstrations, particularly of KISSS showing faster wetting zone, uniform crop growth and water savings, several farmers were encouraged to evaluate and monitor either KISSS and/or IWRS under their farm management regimes. We report on some of the key lessons learnt when engaging farmers to adopt water saving technologies and we also relate difficulties encountered in the field to make the technology work.

INTRODUCTION
Annual potable water use in the Sydney area by commercial horticulture is estimated at 10,000 megalitres. Vegetable farmers in the Sydney region intensively use potable water, mostly with overhead sprinkler systems resulting in unnecessary water wastage due to evaporation, runoff and deep drainage. Furthermore, nutrient runoff from farms is a serious on-going concern, leading to water quality degradation in the area. Reliable access to water has been identified as one of the major limitations to growth and continued sustainability of the peri urban horticultural industry (Hamilton et al., 1995; HAL, 2003). Consequently there has been a growing concern among researchers and development organisations to examine and develop environmentally friendly irrigation and water harvesting systems that improve water productivity and help conserve potable

water supplies. These actions should contribute to the future sustainability of water resources (Maheshwari and Connellan, 2004).

As a consequence of the drought and the severe water scarcity in NSW, in 2006 we commenced the evaluation of two innovative technologies, viz., Kapillary Irrigation Sub-Surface System (KISSS) and the Irrigation Water Recycling System (IWRS) to save potable water for irrigation to vegetable crops under farmer's situations in Sydney region. KISSS was developed by an Australian company, Irrigation and Water Technologies Pty Limited (IWT), and applies water directly to root zone of plants with a minimum of water loss through runoff, evaporation and deep drainage. The system delivers a significant improvement in water application efficiency over sprinkler irrigation systems and traditional drip irrigation systems. Also, since the water is applied below the surface, the water wastage due to evaporation is almost eliminated. Experience has shown that the KISSS system has the potential to save significant volumes of water, estimated to be up to 50%. On the other hand, the IWRS collects irrigation and rainwater runoff from cropped areas during sprinkler irrigation and rain events and stores this within the farm in an existing water storage facility for recycling for the next irrigation. The IWRS is designed to improve the availability of the farm's irrigation water supplies and, at the same time, reduce nutrient runoff from the farm.

The overall objectives of the study were twofold. Firstly, we wanted to gain an insight into and have a better understanding of farmers concerns and issues when faced with adapting to new technologies. Our second objective was to evaluate these technologies (KISSS and IWRS) under field situations and quantify any benefits that may arise from potable water savings and long-term benefits to the local environment.

METHODOLOGY

In our study we are using a participatory approach involving farmers, advisory staff (UWS and NSW DPI) and other stakeholders such as IWT and farmer associations. The following key steps are being used to undertake the evaluation of irrigation technologies at farmer's farms.

- Preliminary meetings: Initial meetings of all the collaborators from University of Western Sydney, NSW Department of Primary Industries and industry partners (Irrigation and Water Technologies Pty Limited) were organized to plan different activities and to develop selection criteria for prospective farmer collaborators for the installation and monitoring of KISSS and IWRS.
- Bilingual Officers meeting: As a large proportion of farmers in the Sydney Basin are of a non-English speaking background, a meeting of Chinese, Cambodian, Vietnamese and Arabic bilingual officers from NSW DPI was held to develop better communication linkage with Non-English speaking farmers about the proposed water saving measures.
- Promotion: Media releases, to promote the study and to elicit farmer collaborators, were made in local newspapers and grower newsletters. The study was also promoted on a "one-on-one" basis by UWS and NSW DPI advisory officers in the course of their normal farm visits.
- Farmer's survey: A survey was conducted to gain an insight into farmer's concerns about the current water crisis, land degradation issues and possible strategies to improve their water management skills. In addition, the survey canvassed possible strategies to improve the marketing of their produce. Both men and women were included in the survey.
- Demonstrations: Demonstrations of KISSS in short 20 metre long beds were organised to encourage potential farmer collaborators to evaluate the KISSS system on their own farms. The demonstrations highlighted the impact of KISSS on soil wetting zone and soil moisture movement, weed infestation, crop growth and water use.
- Installation on working farms: The KISSS system was installed at five farms and the IWRS was installed at three farms.
- Monitoring of KISSS and IWRS: Farms with KISSS and IWRS systems are being monitored for water use, water saving, crop uniformity, weed infestation and productivity.
- Farmer Communication: Continual communication both informally (farm visits) and formally by way of field days and workshops is being used to transfer the results and share experiences with the technologies being used.

- Milestone Reports to Funding Body: Results on water savings, types of crops grown, uniformity in crop growth, crop yields and other issues were collected and reports based on these results were prepared and submitted to funding body.

The key steps taken in this study are shown diagrammatically in Figure 1.

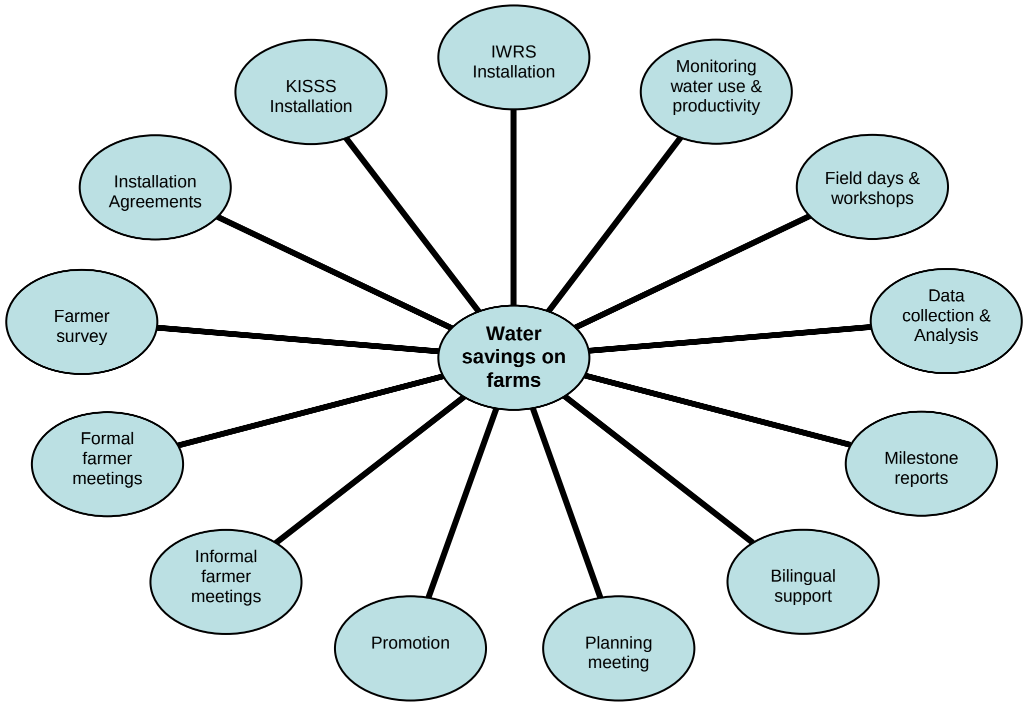

Figure 1: A diagrammatic view of the key participatory steps undertaken in this study

RESULTS AND DISCUSSION

The results of the farmer survey revealed a degree of stress brought on, in part, by the current drought. The farmers experienced higher water demand and increased input cost for the use of potable water for the irrigation of their vegetable crops. In addition, they had other higher input costs such as fertilizers and chemicals to maintain production levels. The farmers also experienced vast variability in vegetable prices and spent considerable time on marketing of produce. In summary the major issues revealed by the survey of small vegetable farmers in Sydney Basin were:

- Increasing water demand due to continuous drought
- Rising cost of water bills
- High fertilizer and input cost of seed, chemicals etc
- Significant price variability of vegetables
- Time wastage on marketing of produce
- Increasing weed problem
- Increasing diseases
- Soil fertility and soil erosion problem

These farmers considered the net return from their vegetable farms have declined drastically during the last decade due primarily to stagnant prices for their produce and rising input costs of fertilisers, water and chemicals. The situation is exacerbated by the current drought and the greater reliance on potable water use to grow their crops and the corresponding increased water costs, currently in excess of $1,300 per megalitre.

Farmers mostly use overhead sprinkler systems for irrigation because of ease of use and because the technology is well understood and generally speaking involves less capital cost than other irrigation systems. In addition, farmers believe that overhead sprinkler systems keep the topsoil moist and the plants turgid during hot weather and that the system can provide some frost protection. Maheshwari and Connellan (2004) also reported overhead sprinklers are the most commonly used irrigation method in Australia for urban irrigation including open space, parks, golf courses as well as for turf and vegetable farms. However, this system is considered inefficient due to loss of water via evaporation, runoff, and deep drainage (Goodwin et al., 2003; Huett 1997). The nutrients removed in runoff from sprinkler irrigated areas may be 'wasted', and contaminate receiving waters resulting in environmental pollution. Moreover the distribution uniformity delivered by the overhead sprinkler irrigation systems at the farms in this study was not particularly good. Typically, test results using catch cans in the growing areas, revealed coefficients of uniformity below 75% (desirable is above 85%) and scheduling coefficients in excess of 2.0 (desirable is as close to 1.0 as possible).

Farmer's Issues

While working with vegetable farmers in the current study, we observed that many factors interplayed to significantly influence their motivation to participate in the evaluation of the proposed new technologies to save water on their farms. Two important factors that were observed to be critical in this study are included (i) the farmer's ethnicity and (ii) their level of technical knowledge (or farming expertise) and their understanding of the effect of drought conditions on farming communities.

(i) Farmer's ethnicity

Initially it was very hard to convince the farmers belonging to one of the ethnic groups about the benefits of KISSS over their current sprinkler system despite free installation of the KISSS system at their farms. These farmers had the perception that KISSS may not work under their situations because the surface soil would not be moist enough given that the drip line is installed 150mm below the surface. These farmers were more comfortable with their current overhead sprinkler systems which they considered much easier to use. They also believed their current sprinkler systems would give them better control over surface soil moisture.

Our initial meetings and subsequent conversations with these farmers about the benefits of KISSS over their current sprinkler system, particularly in terms of water savings and environment protection, did not convince these farmers that benefits could be achieved. In addition there were fears that their soil cultivation practices might destroy the buried irrigation pipes. Consequently we organised demonstrations of the KISSS system utilising short (20 metre long) beds and operated the KISSS system to show its wetting capacity and moisture movement into the soil. The demonstrations were powerful tools and several farmers subsequently agreed to evaluate the KISSS system for irrigation on a range of vegetables at their farms.

(ii) Farmer's technical knowledge and drought implication awareness

Farmers with better technical knowledge and farming expertise were observed to be more motivated. These farmers were also involved more actively during installation and the subsequent monitoring processes.

Farmers with better insight of the water scarcity and its future consequences were more concerned about saving water. These farmers were also more receptive to the idea of trialling new technologies. Their interest in saving water and their concern for the water scarcity can best be demonstrated by their willingness to contribute to the installation costs of the IWRS system to harvest irrigation and rainfall runoff. Some farmers, although acutely aware of the drought impacts and the potential benefits of the IWRS system, did not proceed with the installation of the IWRS due to their financial constraints.

Impact of KISSS Irrigation System on Crop Growth and Other Parameters

This study is currently underway, however early indicators are that there is a distinct improvement in uniformity in crop growth and earlier crop maturity at all the farms in the study. This appears to be related to the uniform wetting of beds obtained with KISSS. This visual appraisal will be confirmed in future analyses.

The estimation of potable water savings due to the installation of KISSS is not straightforward. It needs to take into account the weather conditions for the period of monitoring. For example, water savings based on observed water meter readings should be adjusted (reduced) if the monitoring period is significantly wet compared with the benchmark year. For this reason, we outline below the methodology used to calculate the water savings.

The change in water use from one year to the next is influenced by changes in rainfall, evapotranspiration (ET), cropped area values and the installation of the KISSS. In other words, the change in water use in the current year compared with the benchmark year is a function of changes in the amounts of rainfall, evapotranspiration and cropped area values and water saving due to KISSS. Mathematically, this can be expressed as follows:

$$\Delta WU = f(\Delta R, \Delta ET, \Delta A, WS) \tag{1}$$

Where ΔWU = Change in water use between the benchmark year (2005-06) and the current year (2006-07),

ΔR = Change in water use between the benchmark year and the current year due to rainfall

ΔET = Change in water use between the benchmark year and the current year due to ET

ΔA = Change in water use between the benchmark year and the current year due to cropped area, and

WS = water saving due to the installation of the KISSS.

For the calculation of water saving due to the installation of the KISSS, we make the following assumptions:

- The effects of changes in rainfall, evapotranspiration and cropped area are accounted by proportionately adjusting the water use in the current year.
- The irrigation practice of the farmer does not change except the installation and use of KISSS.
- The effective rainfall generated has a similar trend from one year to the next.
- The cropped area under KISSS does not change during the period of calculation.

The benchmark period for the calculation in this report is November 2005 – October 2006 and water saving calculation period (referred here to current year) is November 2006 – October 2007. As per volume balance for the two periods, the volume of water used in the benchmark year is related to the water used in the current year by the following equation:

$$V_b = V_c + \frac{(R_c - R_b)}{R_b} \cdot (V_b - V_c) - \frac{(ET_c - ET_b)}{ET_b} \cdot (V_b - V_c) - \frac{(A_c - A_b)}{A_b} \cdot (V_b - V_c) + WS_c \tag{2}$$

Where V_b = the volume of potable water used (kL) during the benchmark year (November 2005 – October 2006),

V_c = the volume of potable water used (kL) during the current year (November 2006 – October 2007)

R_b = Total rainfall (mm) during the during the benchmark year,

R_c = Total rainfall (mm) during the during the current year,

ET_b = Total evapotranspiration (mm) during the during the benchmark year,

ET_c = Total evapotranspiration (mm) during the during the current year,

A_b = Total cropped area (ha) during the during the benchmark year,

A_c = Total cropped (ha) during the during the current year, and

WS_c = Water saving (kL) due to the installation of the KISSS in the current year.

By rearranging the terms in Equation 2, the water saving due to the installation of the KISSS can be calculated as

$$WS_c = (V_b - V_c) - \frac{(R_c - R_b)}{R_b} \cdot (V_b - V_c) + \frac{(ET_c - ET_b)}{ET_b} \cdot (V_b - V_c) + \frac{(A_c - A_b)}{A_b} \cdot (V_b - V_c) \quad (3)$$

Equation 3 was used for calculating potable water savings for the KISSS in this project.

The rainfall and pan evaporation values for the various field sites were obtained from the Bureau of Meteorology and cropped area was provided by the individual farmer. The evapotranspiration for the sites was calculated by multiplying the pan evaporation values by a factor of 0.8.

It can be seen from Equation 3 that if rainfall in the current year is more than the benchmark year, then there will be additional water input to the irrigated area due to rain and will reduce the irrigation water requirement. This means, the change in water use needs to be proportionately reduced to give correct savings in potable water use.

Similar interpretation can also be made for evapotranspiration and cropped area. Equation 3 also indicates that the difference between the effect of increased rainfall and increased evapotranspiration and cropped area are in reverse direction (i.e., any increase in values of evapotranspiration and cropped area will increase the total irrigation water use and therefore will proportionately increase the water savings).

Estimation of Potable Water Saving with IWRS

The estimation of water savings with IWRS is relatively straightforward since the water saving is directly related to the rainwater and irrigation runoff harvested and collected in the tanks. In some situations, for obtaining the potable water savings, there may be a need to adjust the value of rainwater harvested for any losses due to evaporation or seepage from the dam area. However, as explained below, there was no adjustment due to the losses required for the three sites in this project and so the water saving was equal to the volume of runoff harvested and metered.

The evaporation and seepage losses of water from the main storage dams at two sites were occurring before the installation of IWRS, and therefore there were no extra losses after the installation of IWRS. For this reason, we did not need to account for these losses while calculating the water saving at the two sites. At the third site, the harvested water is pumped straight into the main water storage tank, and as such there are no evaporation and seepage losses.

Summary of Water Saving by KISSS and IWRS

There was a total of 5354 kL of potable water saved after the installation of KISSS and IWRS from November 2006 to October 2007. KISSS resulted in 4775 kL of water saving, accounting for 89% of total water saved. There was 580 kL of potable water saved by IWRS system, contributing 11% of total water saved during November 2006 to October 2007. Based on five sites, the average water saving through KISSS was 18%. However, larger savings are expected in the future as farmers become more experienced with the management of this system and are prepared to adopt irrigation schedules based on water demand. Simple control systems based on soil moisture will be evaluated to assist this process. Since the installation of IWRS system was only completed by the end of July, the water saving by IWRS contributed only for about 4 months. With the initial problems solved and all the sites contributing to water saving for the entire year, we expect much greater water saving during next year from both IWRS and KISSS.

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Figure 2: Introducing KISSS to a potential collaborating farmer.

Figure 3: Installing KISSS on a study farm.

Figure 4: The IWRS system installation.

Figure 5: Explaining KISSS operation at one of the field days on a collaborators farm

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