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Tracking the Value of an Innovation through the New Product Development Process: The IrriSat Family of Agricultural Decision Support System Tools[1]

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Abstract

The paper describes an attempt to improve the uptake of a new agricultural Decision Support System (aDSS). The approach was to design it with an understanding of the successes and failures of predecessors and of the changes in patterns of relevant technology use over time, the "usage context". Even though its predecessor, IrriSatSMS, showed great potential in pilot seasons, that system failed to be commercialised successfully. An investigation into whether this failure can be attributed to "technicentric design" – an aDSS problem lamented by many authors of papers on aDSS in the 2000s – is undertaken. Some relevant aspects of the design of the new aDSS system, IrriSat, are outlined to illustrate how some of the commercialisation issues faced by IrriSatSMS and other aDSS may be overcome. Important considerations impacting the usage and uptake of aDSS include the changing landscape of IT, digital agricultural data and farming lifestyle since the 2000s. Finally, remaining and emerging issues faced by systems like IrriSat, are considered.

These considerations indicate that while commercialising a new aDSS is always going to be risky for an organisation, particular aDSS design choices that are now available, such as the use of cloud computing, can reduce running costs and staffing effort significantly, thus substantially reducing that risk for certain aDSS types. Also evident is that a step change in IT use in farming since the first trials of IrriSatSMS, in Australia at least, has seen the evaporation of many issues that once plagued aDSS use regarding farmers' interactions with IT systems. However, new issues, such as data deluge, have surfaced. With these technology and technology usage changes, I conclude that the pessimism shown in aDSS papers in the 2000s was based on factors that are no longer dominant in the aDSS landscape; a paradigm shift has occurred. However, the new paradigm has its own issues. Experience in other areas indicates that this paradigm's issues can also be overcome and thus the future for

[1] The author acknowledges the Cotton Research and development Corporation and the NSW Department of Primary Industries, for coordinating and running interactions with the trial users of this system; cotton farmers of northern NSW and southern Queensland, for their willingness to participate in trials, even when the return on their time spent wasn't evident; and finally, Jamie Vleeshouwer, for his excellent front and back-end software engineering that actually implemented the recent IrriSat system.

aDSS in general, and perhaps IrriSat specifically, looks bright. A number of challenges are revealed that can impact the development and commercialisation of new products. Central among them is the importance of tracking changes in the usage context of, and therefore competition for, the new product, and related impacts on product value to the user.

***Key words*:** Decision Support System, agriculture, irrigation, cloud computing, informatics, Australia

Introduction

In the first decade of the 21st century, a pessimism took hold about the broader adoption of objective agricultural Decision Support Systems (aDSS). This was solely based on the systems' advancing technical capability. McCown (2002) and Carberry et al. (2002) lamented an aDSS past where sophisticated models were built by scientists and engineers that were ultimately unsuitable for farmers to use due to cost, complexity or their inability to work in the "real world". Those papers, perhaps best summarised by Matthews (2008), looked to leverage participatory action research (PAR) to better engage potential users in system development, thus making tools more appropriate for them. They aimed to find the most appropriate places for their aDSS deployment, based on "institutional and socio-political" considerations, not just the "technical or theoretical aspects of the tools themselves".

In the Australian irrigation DSS context (a subset of aDSS) survey results of system use from the middle of last decade bear out Matthews: Inman-Bamber and Attard (2005) show that there were then only 21 systems in operation Australia-wide but most with only a dozen or fewer users.

Several years later, Car et al. (2012) showed that a technical DSS (IrriSatSMS), created without PAR but with an eye to simplicity of use, could deliver utility and see good uptake, at least in trial phases where cost of use was low or zero. Survey results of participants in that aDSS trial, also related in that paper, showed many of them also used very costly soil moisture probes – a form of aDSS – which indicates that cost alone was then not necessarily a barrier for use. While IrriSatSMS was much hyped at the time (including winning an industry design award[2]) it has, nevertheless, joined the ranks of many other aDSS that showed promise but, a few years on, are no longer in operation.

In this paper three main tasks are undertaken: first, a follow-up on the fate of the IrriSatSMS DSS described in Car et al. (2012) and an analysis of the attempt to commercialise it (aDSS history must be reviewed in order for it not to be repeated!). Second, a discussion about a new aDSS derived from IrriSatSMS, simply titled IrriSat, that is now under trial. While many of the technical details of IrriSat have been published previously (Vleeshouwer, Car and Hornbuckle, 2015), here an analysis is given of its *raison d'être* – how it attempts to overcome some of the issues faced by IrriSatSMS, particularly those relating to attempts at commercialisation – and its usage to date. The new light this sheds on points of view taken by McCown (2002), Carberry et al. (2002) and Matthews (2008) are specifically indicated. Third, the changing landscape of IT, digital agricultural data and farming lifestyle since the 2000s in Australia is considered, the effect this has had on aDSS and what effects it seems likely to have in the future.

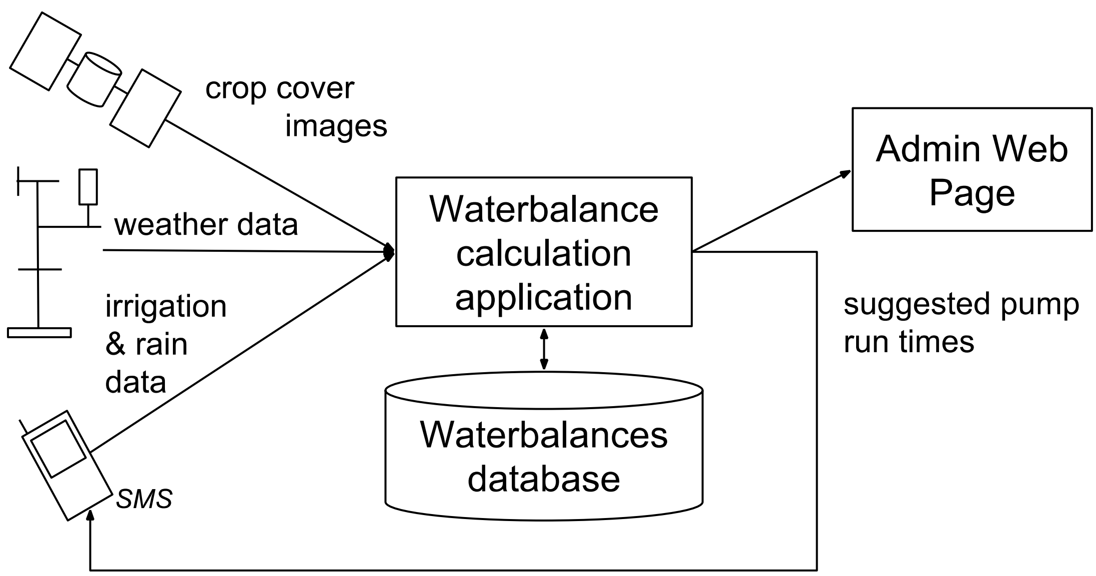
The Fate of IrriSatSMS

IrriSatSMS was an aDSS that used semi-automated processed satellite data and automatically collected local weather data to estimate daily crop water use. That information, along with

[2] Irrigation Australia Ltd. award for "Best New Irrigation Product", 2010.

farmer-collected rainfall and irrigation values, was then used to run a daily timestep waterbalance model, the results from which were sent to the farmer daily via mobile phone Short Messaging Service (SMS) (Car et al., 2012) (see Figure 1). The results gave an objective indicator of tactical (day-to-day) potential crop water requirements at the field scale. They indicated to the farmer how long to run his pumps for to return his crop's waterbalance to zero. This was advice he could choose to follow or to use as a potential only, for instance, varying applied water around the figures as desired to achieve a particular crop outcome, such as stressed red grapes for wine quality. The system was able to be operated by farmers entirely via SMS and was scalable to many hundreds of farms with low increasing system cost.

Figure 1: A system diagram outline of the IrriSatSMS system (after Car et al., 2012)



Attempted commercialisation of IrriSatSMS

After IrriSatSMS showed good uptake results in trial seasons (Car et al., 2012), the research body mostly responsible for its development, the Commonwealth Scientific and Industrial Research Organisation (CSIRO), attempted to commercialise it in order that it might be run continuously for Australian irrigators. This is a normal process both for the CSIRO and for the multi-agency collaboration that funded its development, the Cooperative Research Centre for Irrigation Futures (CRC-IF), both of which have been involved with numerous commercialisation projects in different research areas.[3]

This author was involved in the following steps that were undertaken to assist with commercialisation:

- Generation of a report aiming to detail "the conceptual framework and the practical elements that need to be assembled to make such a service operational" (Hornbuckle et al., 2009);
- Personnel resource allocation to improve the IrriSatSMS software for continued operation;

[3] It is recognised that commercialisation of an aDSS is not the only possible outcome criterion for success. For example, influencing behaviour at a large scale could be achieved through user learning, not necessarily by selling licences for, or subscriptions to, systems; however, for a system that provides watering advice on current atmospheric and crop conditions, continuous operation is required for users to gain benefits, thus the system must outlive limited research funding time-spans and thus commercialisation, of some form, is necessary for the success of this aDSS.

- Open Source licencing of the IrriSatSMS software;
- Engagement (travel to and conversation with) agricultural service providers to transfer knowledge of IrriSatSMS operations;
- Arranging a small start-up grant to be given to assist the targeted commercialising partner with taking on new skills.

The report lists three main elements to be assembled in order to operationalise IrriSatSMS (Hornbuckle et al., 2009):

1. Data sourcing – getting the satellite, weather and farmer data the system needs to run;
2. Server systems – writing the IT systems that do the work;
3. Verification – of IrriSatSMS results by comparison with measured on-ground results.

In 2010, the CRC-IF entered into negotiations with a single community agricultural information service provider to commercialise IrriSatSMS (CRC for Irrigation Futures, 2010). Care was taken to describe the CRC-IF's processes for operating the system in order to inform the would-be commercialiser of the tasks they were likely to encounter.

Reasons for failed commercialisation

Despite the steps listed above, commercialisation of IrriSatSMS failed with the single commercialising partner not replicating the research agency infrastructure or offering the service. This was due to a range of factors which I list from memory, having been involved, and from recent interviews conducted for this paper with the researchers and the commercialising partner.

As seen from the research agency side[4], the issues were:

- the investment required versus uncertain income;
- the availability of commercial partner's skilled (GIS) personnel for data processing.

The first issue was a risk that is borne by any organisation adopting a new research product. It is somewhat unavoidable but certainly may be reduced by cheap deployment costs (which became a design goal of the successor aDSS, IrriSat). The second issue may have been somewhat commercialisation-partner specific but, from this author's interactions with agricultural bodies, it is widespread: agricultural service providers, such as agronomists and consulting companies, do not typically have either spatial informatics capacity or high-level IT training.

Dependence of service providers on these skills for DSS delivery may be greatly reduced via system design. Table 1 lists design choices that specifically cater for GIS skill-dependence. Additionally, IT skills in the agricultural service provision sector are growing alongside such skills in the agricultural sector as a whole.

It is also somewhat avoidable through technological means where the specialist knowledge required to train others in a tool's use may be reduced. This is also a design goal of the new IrriSat and Table 1 outlines the specific issue faced by this commercialising partner relating to GIS data processing.

From the point of view of the commercialising partner[5], the major issues were:

- IrriSatSMS's lack of a polished user interface;
    - the research project's interface was sufficient for use but not perfect;

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[4] Personal Communication with Christen, E.W. in March 2016. He was the senior CSIRO research scientist involved in the project.

[5] Personal Communication with Argus, S. in March 2016, formerly principal of the commercialising partner.

- the availability of staff for user engagement and usage training;
- the lack of support for the commercialising partner from government farmer liaison bodies.

The first issue above is not uncommon for any new technological system. Later I describe how the User Interface (UI) of IrriSat has evolved from that of IrriSatSMS to address this issue and discuss changes in users' acceptance of IT, especially their familiarity with the sorts of UIs relevant to aDSS such as IrriSat. The second may appear not to be avoidable being, seemingly, a factor of the specific commercialising partner's business but in fact it too, as above, can at least be partially addressed by a DSS design that reduces required training for use and through growing users' familiarity with relevant technologies. The third issue from the commercialising partner's point of view can only be addressed by government and industry collaboration and this has happened with IrriSatSMS's successor.

This author, who was the research agency's DSS engineer for IrriSatSMS, recalls the reasons for the failed commercialisation being:

- the investment required versus uncertain income;
    - uncertainty around system costs and operations due to lack of experience in the required IT fields;
- an unwillingness on the behalf of commercialising partners' staff to adopt new tools (mostly IT) and approaches towards service delivery to farmers.

Of the two issues identified by this author, the first has been dealt with above and the second, once again, is at least partly addressed by changing use of technology in the agriculture sector which affects service providers in it as well as farmers.

A New aDSS Design

Successor design goals

In mid-2014, a successor project to IrriSatSMS was initiated by the Cotton Research and Development Corporation (CRDC)[6]. The publicly stated design goals of this successor system (Hornbuckle & Car, 2013) were to:

- implement a prototype operational aDSS for cotton growers in Australia based on the IrriSatSMS system with 100+ farmers;
- use scalable technologies for the aDSS to allow for easy growth from small numbers of users to large, potentially all the cotton growers of Australia;
- use the latest satellite remote sensing products to generate field-specific crop waterbalance advice;
- provide forecast waterbalance advice;
- deliver advice to farmers via SmartPhone applications.

Most of these goals were simple updates to the design goals of the IrriSatSMS system from which IrriSat was derived; however, from the start of the IrriSat system build, technological attempts were also made to address some of the issues with IrriSatSMS commercialisation. Those issues, and the IrriSat system design features that attempt to address them are related in Table 1. In addition, the institutional arrangements delivering the new IrriSat aDSS also attempted to overcome some of the other issues with IrriSatSMS commercialisation. They are related in Table 2.

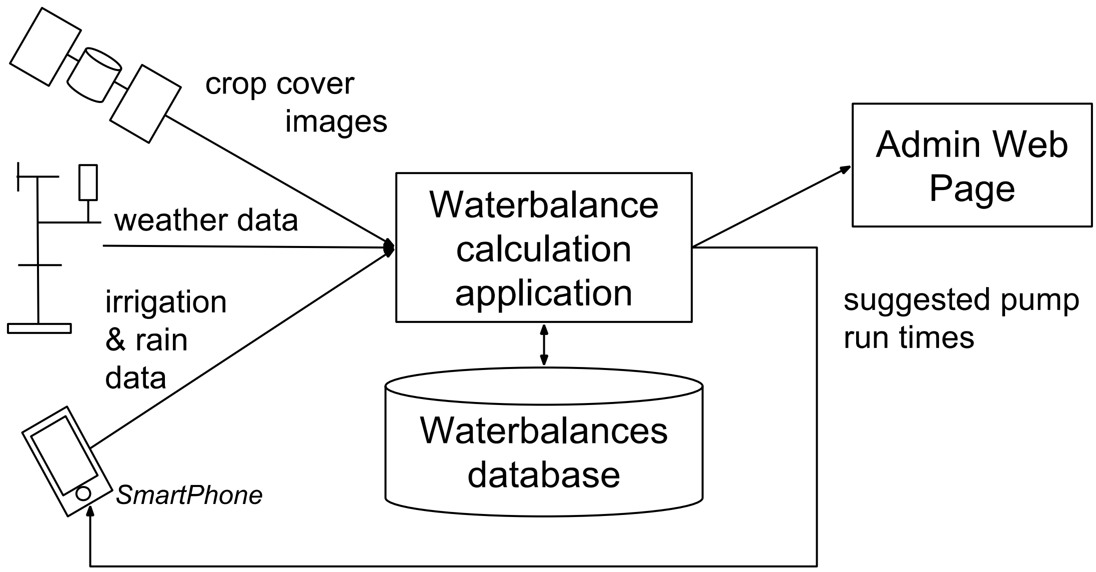
[6] http://www.crdc.com.au

In building the aDSS for a specific industry group, the CRDC, its scope was limited to a particular crop type, cotton; however, only the last of several equations applied to satellite imagery to generate crop coefficients are cotton-specific; all other elements would remain the same for other crops. The cotton-specific equation details are given in Montgomery (2015).

IrriSat system design

At the highest level, Figure 2 represents architecture of IrriSat as well as IrriSatSMS with just a single change needed: the block "SMS Messages" needs to read "SmartPhone Messages" which indicates that, from the data flow perspective, the systems are functionally equivalent albeit with the update in mobile phone delivery from SMS to SmartPhone application. However, they operate very differently from a systems manager's point of view.

Figure 2: A system diagram outline of the IrriSat system (after Vleeshouwer, Car and Hornbuckle, 2015)



Public cloud-based infrastructure is used for almost the entire IrriSat system. Specifically, Google Earth Engine (GEE)[7] is used for fully automated satellite data acquisition and processing, in place of the previous IrriSatSMS semi-manual, semi-desktop processing workflow. Furthermore, the Google App Engine (GAE)[8] is used for waterbalance calculations and waterbalance data storage (Vleeshouwer, Car and Hornbuckle, 2015) in place of IrriSatSMS's use of a virtual server. Both the GEE and GAE applications are fully automated and auto-scale with only service fees changing, meaning that non-erroneous processing of one or one thousand users' waterbalances. The requisite satellite data requires precisely the same DSS management effort, which is none. The use of GEE also allows IrriSat to access and blend imagery from several LANDSAT satellites (currently 7 & 8 and historically 5 & 7), not all of which were available at the time of IrriSatSMS' creation (8). Also, GEE will acquire new imagery over time, meaning that IrriSat's base data will grow in volume, acquisition frequency and likely precision over time with continual minor changes required in order to leverage new data.

The use of public cloud infrastructure for the entire IrriSat system also means that there is no need

[7] https://earthengine.google.com/

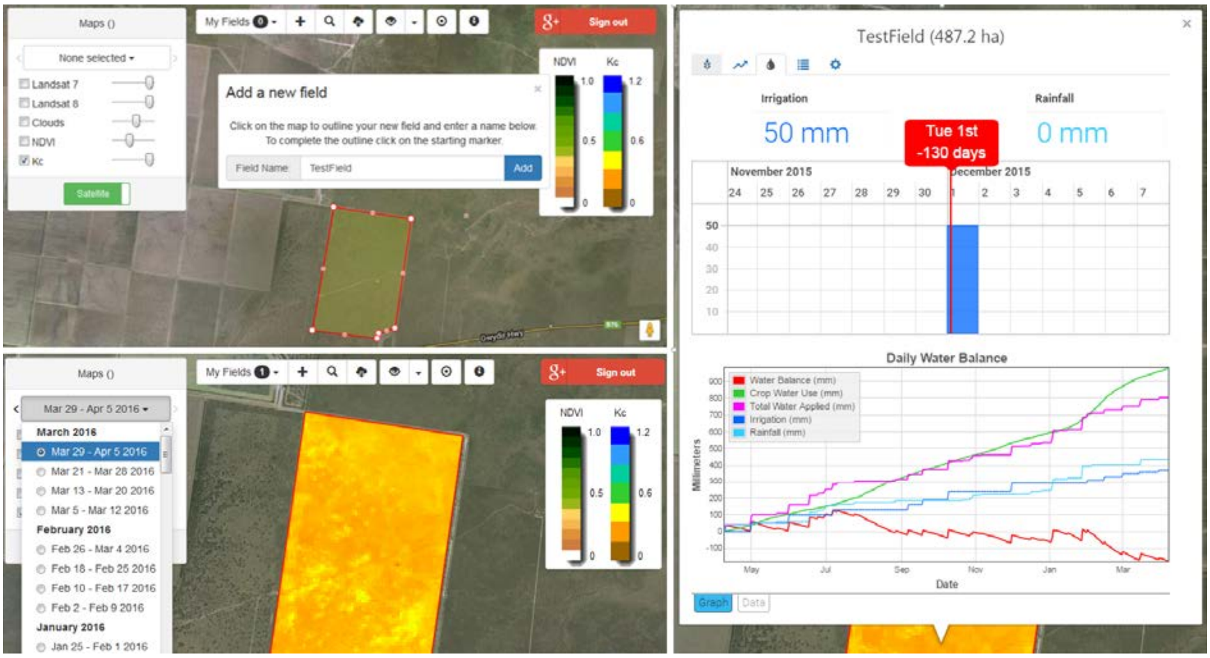
[8] https://appengine.google.com/start

for commercialising partners to implement a clone of the infrastructure used by the aDSS developers to operationalise the aDSS: they can either take direct ownership of the aDSS and its infrastructure, since it's not within a private organisation and the "keys can be handed over", or they can duplicate the system and infrastructure within the same public cloud almost with the "click of a button" as many public clouds, including the relevant ones for IrriSat, offer this sort of replication.

User Interface

IrriSat presents a web-based interface to managers and users that is conceptually similar to that presented by IrriSatSMS but with the addition of new features provided by the IrriSat architecture and support for a much greater range of user actions. It allows users to enter rainfall and irrigation values for multiple crop fields and displays waterbalance traces for them generated using those inputs and crop evaporation as per Vleeshouwer, Car and Hornbuckle (2015). Figure 3 shows some images of its web UI. Some similar images of IrriSatSMS's web interface are show in in Figure 4 for comparison.

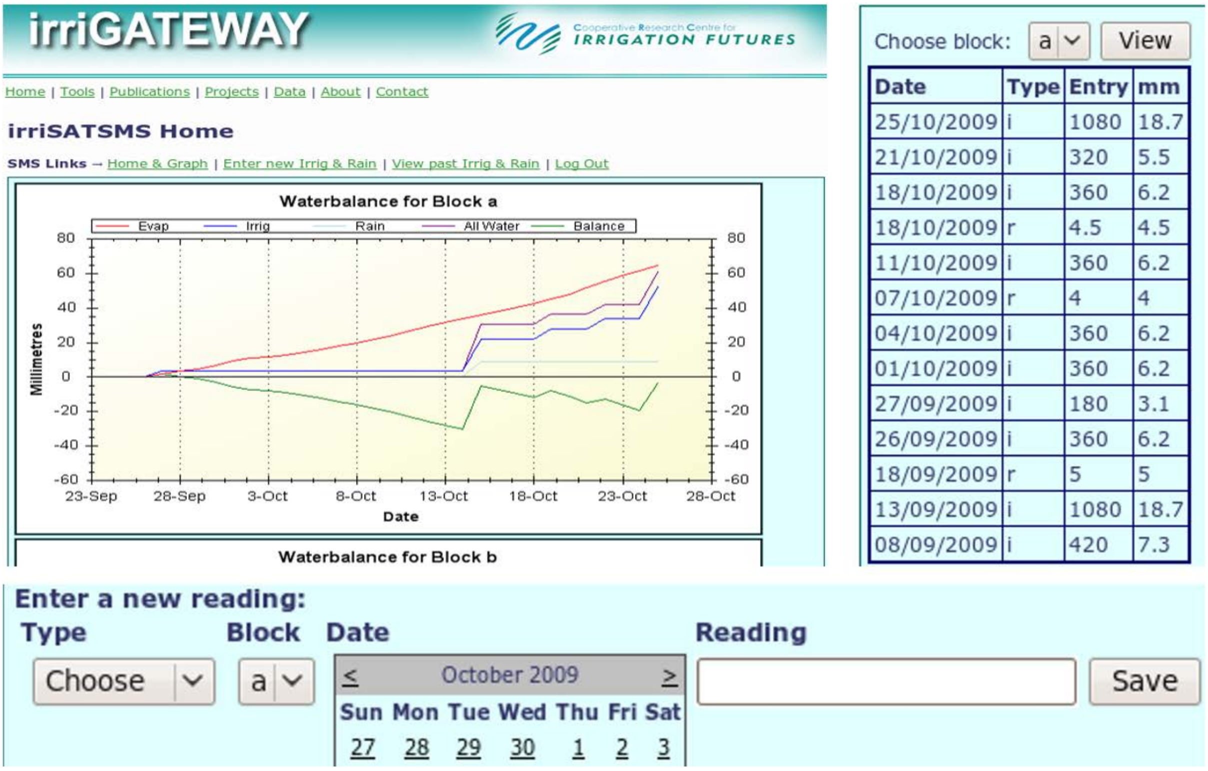
Figure 3: Three parts of the IrriSat web UI. Clockwise from top left: a user's new test field marked out ready for analysis; the waterbalance graph of the test field; the test field's crop coefficient taken from blended satellite imagery (LANDSATs 7 & 8)



Compared with IrriSatSMS' web UI, IrriSat's is 'polished' with better aesthetics and operations, for example input validation within form elements that catch incorrect values, such as impossibly large rainfall readings. It also provides for a wider range of user actions; for example, due to the use of map drawing toolkits, the IrriSat UI allows users to mark out their own fields and save them for analysis, as shown in Figure 3. For IrriSatSMS previously, field marking had to be done by a project staff member and loaded into the system for the irrigator. This did not allow irrigators to change their fields easily. Due to IrriSat's cloud-based infrastructure, it is able to recalculate the waterbalances for a user's fields after each data entry of rainfall or irrigation *on the fly*, meaning the user sees instantaneous changes in the waterbalance graph.

Changes like these do not affect the core operations of the crop waterbalance but greatly enhance the user experience of interacting with the system. The SMS interface present in IrriSatSMS was not continued in IrriSat due to the familiarity of intended users with SmartPhones and Internet interfaces. Initially, IrriSat planned on releasing a SmartPhone mobile UI (Vleeshouwer, Car and Hornbuckle, 2015) for irrigators to use in the field; however, the web UI is thought to be sufficient for the first few season's testing thus a SmartPhone UI may be developed at a later date.

Figure 4: Three parts of the IrriSatSMS web UI. Clockwise from top left: a crop's waterbalance trace; past irrigation (i) and rainfall (r) data inputs for block 'a'; the web form for adding irrigations and rainfall via the web UI



The improvements in IrriSat's web UI over IrriSatSMS' are due to three things:

1. continued investment in aDSS research and development;
2. growing experience by the developers with particular aDSS UI issues;
3. changing web technologies allowing for more UI options at lower cost.

IrriSat UI improvements, where relevant to issues with IrriSatSMS' failed commercialisation, are given in Table 1.

IrriSat institutional arrangements

Unlike IrriSatSMS, which was built by a research agency as a proto-operational, proof-of-concept system (with high expectations of an easy transition to operations that were never realised), IrriSat was built for an agricultural community agency, the CRDC[9] that intended, right from the start of the project, to operationalise it (Hornbuckle & Car, 2013). This meant that IrriSat would not need to go through a quasi-tender process for commercialisation upon project completion. However, it would/may still have to go through a technological transition (see below). In working with an industry association that is able to commercialise tools right from project inception, IrriSat is following the first commercialisation option Case Study presented in Hornbuckle et al. (2009) *'By*

[9] http://www.crdc.com.au

Government Institution'. Table 2 lists the major institutional arrangements around IrriSat – both those related to the commercialising partner and others – and the IrriSatSMS commercialisation issues they address.

Table 1: Issues with IrriSatSMS commercialisation and the corresponding IrriSat design feature attempting to deal with it

Issue	**Design Feature**	**Explanation**
Investment uncertainty versus uncertain income	Auto-scaling infrastructure	Reduces installation costs to zero; reduces running costs to as-needed
Availability of commercial partner's skilled (GIS) personnel for data processing	Fully automated satellite data processing	IrriSat automatically blends imagery from a range of satellite[10], removing cloud effects and calculates crop coefficients from NDVI[11]. No manual processing is required thus no staff investment required
Lack of a polished user interface	Polished UI	Compared with the web & SMS UIs of IrriSatSMS, IrriSat UI allows for better input validation, more functions and faster feedback on changes
Availability of staff for user engagement and usage training	Familiar UI	The IrriSat UI consists of web maps, forms and other components now commonly found in many web pages. This means its use will be instantly familiar to users or that they will require very little training for its use Some user actions required for IrriSat are now common across other Internet tools too, for example, the IrriSat log on process is the same as for Google's GMail email product and uses the same credentials

Table 2: Issues with IrriSatSMS commercialisation and the corresponding IrriSat institutional arrangement attempting to deal with it

Issue	**Organisational Arrangement**
Availability of commercial partner's staff for user engagement and usage training	Partnership with a commercialising partner over many years of product development enabling skills build-up if necessary
Lack of support for the commercialising partner from government farmer liaison bodies	Partnership with a government-assisted commercialising partner agency
Unwillingness on the behalf of commercialising partners' staff to adopt new tools (mostly IT) and approaches towards service delivery to farmers	As per first point above. Additionally, the CRDC is an agency that, due to government support, has a longer horizon than a small enterprise

[10] All these as available in Google Earth Engine: LANDSAT 5, 7 & 8 as well as MODIS Terra
[11] Normalised Difference Vegetation Index, see (Vleeshouwer, Car and Hornbuckle, 2015)

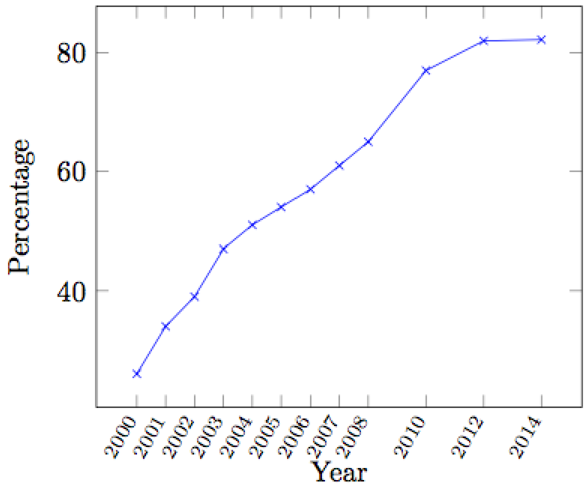
The Changing Australian Farming Technology Landscape

High levels of Internet access and SmartPhone ownership, detailed in the following sections, mean that virtually all Australians are now familiar with the Internet, web pages and the other IT tools used for the user interfaces of aDSS like IrriSatSMS & IrriSat.

Changing Internet access

Since the first field trials of IrriSatSMS in 2009, the percentage of Australian rural households with Internet access has increased from 65 to 82 in 2014 (see Figure 5).

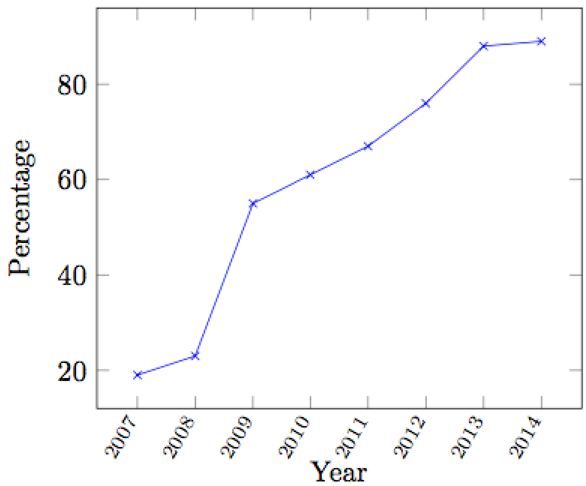
Figure 5: Proportion of Australian rural households with internet access (Australian Bureau of Statistics 2009, 2011, 2014 & 2016)



While these figures for rural households are approximately 10% lower than for urban households, Internet access all over Australia is high and appears to have reached saturation levels with virtually no growth from 2012 to 2014. These high penetration rates mean that designers of aDSS for the Australian market can rely on the Internet as a delivery mechanism for most of their potential users.

Changing mobile technology ownership

Figure 6: Proportion of Australian mobile phones that were SmartPhones (Mackay, 2014)



Australia has some of the highest SmartPhone ownership rates in the world with 74% of adults owning at least one in 2015 (Australian Communications and Media Authority, 2015). Additionally, the percentage of mobile phones in Australia that are SmartPhones is now greater than 89% (Mackay, 2014, p.9). Importantly for IrriSatSMS & IrriSat, SmartPhone penetration as a percentage of total mobile phones in Australia grew rapidly from around 25% when IrriSatSMS was first field-trialled in 2008 to around 60% at its last trial in late 2009 (see Figure 6). The SMS interface for IrriSatSMS was built specifically to cater for irrigators who had mobile phones but not SmartPhones.

Changing data availability

While not listed above as a primary issue for IrriSatSMS' commercialisation, the ability to access quality data required for its waterbalance calculations in particular geographical areas was a real one noted by this author. The trial seasons for IrriSatSMS were not limited by satellite data access as the particular datasets used – LANDSAT 5 & 7 – covered all of Australia, but were confined to zones of uniform weather types around individual weatherstations. In 2007 at IrriSatSMS' inception, there were three major sources of weatherstation data in Australia: (1) the Australian Bureau of Meteorology's (BoM) national observations network [12]; (2) a few dedicated agricultural weatherstations maintained by state departments for agriculture and primary industries; and (3) weatherstations supplied by CSIRO, the IrriSatSMS developing agency, for IrriSatSMS. Data from the BoM weatherstations was unsuitable for the waterbalance calculations due to differences in evaporation calculation techniques and data from all of the departmental stations was impossible to access in a timely fashion due to restrictive IT policies preventing its automated release. This meant that all IrriSatSMS trials relied on CSIRO-supplied weatherstations.

The range of weatherstation data sources in the cotton-growing areas of New South Wales, Australia, in 2014 able to be used in the trialling of IrriSat was much increased from those available to IrriSatSMS in 2007. In 2014, data could be automatically collected from: (1) expanded state departments of agriculture weatherstation networks; (2) multiple private weatherstation networks; and (3) IrriSat-dedicated CSIRO stations. Additionally, the BoM is looking to produce a nation-wide gridded data evaporation product that will likely be available as IrriSat trials conclude.

Data from these weatherstations can be automatically and reliably collected due to a change in general web development which emphasises the delivery of data and function delivery via Application Programming Interfaces (APIs) that then power human-readable web UIs over web UI-only delivery[13]. Web pages made in this way make the data they display available for access independently of the particular web UI they deliver. The IrriSat system is able to pull in data from many stations not managed by CSIRO using direct API access. This expands the possible IrriSat application areas at very low (almost zero) cost as opposed to expansion of IrriSatSMS which required the placement of a custom-built weatherstation. Figures 7 and 8 show human-readable and machine-readable versions of the same weatherstation's web page respectively.

The number of weatherstations which publish data to the web in any form has grown dramatically with a decrease in the cost of mobile phone 3G and 4G technologies that allow connected devices to use the HyperText Transfer Protocol (HTTP), and in the cost of the physical weatherstation electronic components. In 2007, each CSIRO station used a fixed landline phone connection for data transfers that cost more than $AU300 per month. Telecommunications costs reduced to about 10% of that

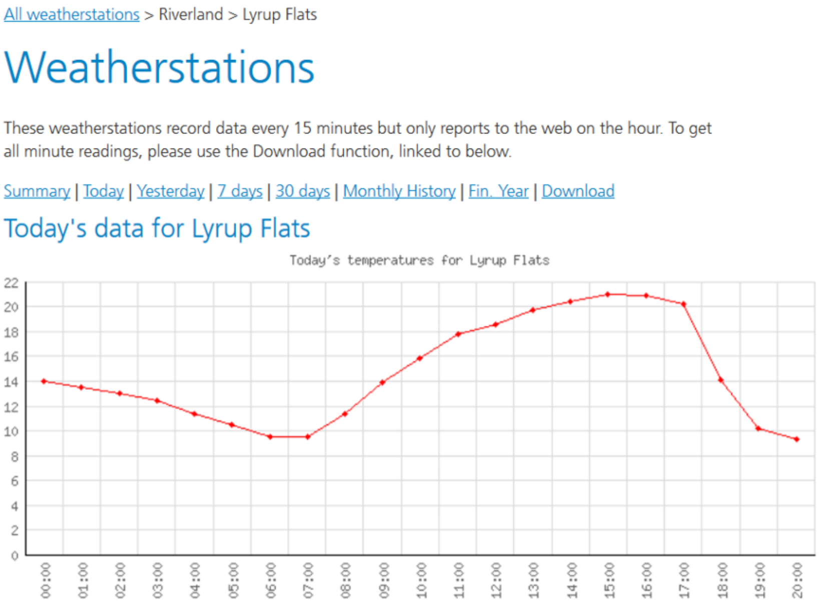
[12] http://www.bom.gov.au/climate/data/stations/

[13] See this from 2011 for an in-depth discussion of the issue as seen during the rise of APIs: https://code.tutsplus.com/articles/the-increasing-importance-of-apis-in-web-development--net-22368

figure in 2008 with the arrival of a widespread 3G carrier[14]. Current monthly mobile phone charges for CSIRO's weatherstations are approximately $AU15 per month; 5% of the 2007 charges.

The cost of automated weatherstation's hardware, although hard to quantify exactly, has clearly reduced significantly from 2007 to the present. While ultra-cheap 'hobby' units now exist for around $AU100, stations rugged enough and containing components of sufficient quality to be useful for farm applications, and which may publish information to the web, are generally available now for a few thousand dollars which appears to be a reduction of perhaps 80% since 2007. Typically, weatherstations are sold as part of a 'solution' which includes data management with information stored on servers and accessed via web pages.

Figure 7: The human-readable (HTML) web page UI for the Lyrup Flats weatherstation from http://aws.naturalresources.sa.gov.au/samurraydarlingbasin/?aws_id=RMPW05&view=summary



Today's data for Lyrup Flats

Time (CST)	Air Temp °C	App Temp °C	Dew Point °C	Rel. Hum %	Delta Temp °C	Soil Temp °C	Solar Rad W/m²	Wind Avg km/h	Wind Max km/h	Wind Dir °	Rain mm
00:00	14.0	9.6	10.6	80.1	1.9	21.4	2	4.4	10.8	269.4	0.0
01:00	13.5	9.0	10.3	80.9	1.8	20.8	2	5.1	11.7	263.7	0.0
02:00	13.0	8.4	9.3	78.5	2.0	20.5	2	5.6	11.7	275.9	0.0
03:00	12.4	7.4	8.8	78.8	1.9	20.1	2	7.2	15.0	260.3	0.0
04:00	11.4	6.7	8.3	81.5	1.6	19.7	2	5.8	10.8	270.3	0.0
05:00	10.5	5.8	7.8	83.7	1.4	19.3	2	5.8	10.8	274	0.0

The commensurability of evaporation data from weatherstations with Irrisat's equations is still an issue, however, as only calculations made using the ASCE's standardised reference equations (Walter, 2001) are usable and these are not implemented in all systems; many still use those equations' precursors such as the FAO56 equation (Allen et al., 1998).

14 Telstra's NextG network. The current NextG / 4G network coverage for Australia can be found at https://www.telstra.com.au/coverage-networks/our-coverage

The centralisation of a large LANDSAT archive in Google Earth Engine's data repository means the entire archive of such imagery for all of Australia, and updates close to when they are acquired, are available for use via the GEE API. This simple access drastically reduces effort, cost and system complexity for the DSS designer. Competitor systems to the GEE, such as Geoscience Australia's Australian Geospatial Data Cube[15] promise to deliver a greater variety of satellite imagery via a single API. This would enhance the spatial and temporal resolution of systems such as IrriSat.

Figure 8: Data from the machine-readable API for the Lyrup Flats weatherstation corresponding to Figure 7 from http://aws.naturalresources.sa.gov.au/api/data/? timestep=minutes&station_ids=RMPW05&start_date=2015-04-17&end_date=2015-04-17


```
{
  "header": {
    "timestep": "minutes",
    "no_readings": 96,
    "parameters": [
       "aws_id","stamp","arrival","airT","appT","dp","rh",
       "deltaT","soilT","gsr","Wmin","Wavg","Wmax","Wdir",
       "rain","leaf","canT","canRH","batt","pressure",
       "wetT","vp"
    ]
},
"data": [
    ["RMPW05","2015-04-17T00:00:00","2015-10-03T22:34:35",
    13.4,9.4,12.7,95.5,0.4,19.1,2.0,0.0,2.448,8.316,225.0,
    0.2,10.0,1.4,4.4,13.03,null,13.0,14.7],
    ["RMPW05","2015-04-17T00:15:00","2015-10-03T22:34:35",
    13.6,9.7,12.9,95.8,0.4,19.1,2.0,0.0,2.376,6.66,225.0,
    0.2,10.0,1.2,4.2,13.02,null,13.2,14.9]
    ...
  ]
}
```


A growth in the range of types of data sources available to farmers not directly relevant to IrriSat has also occurred in line with cheapening electronics and information technology, too. For example, many companies now offer Australian farmers soil moisture sensor networks that are affordable by small family enterprises where once such offerings were very expensive and affordable for large corporate farms only[16].

Changing information systems use in agriculture

The high levels of internet connectivity across Australia and the high availability of web and Internet technologies, as well as cost reductions in electronics and computer systems more generally, have led to a rapid rise in the use of information systems for agriculture. However, there has also been a substantial rise in the use of non-agricultural information systems in the Australian populous generally, within which Australian farmers must operate. For example, until recently, all major Australian banks offered online banking to supplement in-person banking. Now, online banking is the norm with banks offering either higher fees for in-person banking or not offering it at all. Along with banking, many other financial operations are now required to be carried out online, such as insurance, superannuation, investments etc. and farmers must use these tools just like everyone

15 http://www.ga.gov.au/about/projects/earth-observation-and-satellite-imagery/australian-geoscience-data-cube

16 Measurement Engineering Australia's 'Plexus' (http://mea.com.au/soil-plants-climate/soil-moisture-monitoring/plexus) is a low cost soil moisture sensor system

else. This means they are used to a wide range of information systems use in the non-agricultural parts of their lives. There is much crossover between agricultural and non-agricultural information systems with government and many companies offering online tools for agricultural commodity markets and similar[17].

Performance of IrriSat

IrriSat's first version was completed in time for use over the 2015/16 Australian cotton season which is approximately September 2015 to May 2016. Workshops with target users (cotton irrigators and consultants to them) were held in 2015 to promote the system and system sign-ons were accepted from about September, 2015.

Usability

Once a field is marked out via the IrriSat user interface, the satellite imagery for it going back one year from the present is accessed and processed generating a timeseries of crop coefficients "on the fly" (as the user waits). If irrigation and rainfall events are then added, a crop waterbalance graph can be drawn. These steps are shown in Figure 3. It takes less than a minute for the field marking and satellite data access and processing.

In farmer workshops in 2015, no major issues were discovered with farmers' use of the user interface. It appeared that the relative simplicity and responsiveness of the UI, key design goals (see Table 1), mean some problems encountered with IrriSatSMS use did not appear to arise. For example, errors in irrigation and rainfall data entry – the main source of IrriSatSMS' waterbalances errors – can be seen on the nearly instantaneously-generated waterbalance chart and quickly corrected, all within a single usage session with no need for a support request cycle. With IrriSatSMS, erroneous entries were often only seen after an overnight waterbalance calculation run and then a support request from user to administrator was required to resolve it. This new mode of operations both reduces user frustration and reduces the requirements for system support.

By mid-cotton season 2015/16, over 300 users were signed up to use IrriSat and had registered between one and several hundred fields each. Due to IrriSat's scalable cloud-based architecture, it performs with the same service level regardless of the number of users so that those with hundreds of fields are able to click on them and generate waterbalance charts in the manner described above just as easily as those with one field. No issues relating to high loads on the website due to multiple simultaneous users have been observed, either.

The effort required for irrigators, or consultants on behalf of irrigators, to input rainfall and irrigation records for each field was a problem for IrriSatSMS. It was partially solved with a very simple SMS-based input method (see Car et al., 2012) and limiting irrigators to one field per person. For IrriSat, the SMS input option has been removed and the limit of one field per person too. Over the course of the 2015/16 season, several methods have been tried for easing the effort of data input to IrriSat. While automated rainfall capture from regional weatherstations is not appropriate due to Australian summer rainfall patterns being very patchy, readings from in-field automated rainguages are able to be used. For irrigations, many cotton growers' irrigation schedules are planned long in advance due to irrigation water ability and thus per-field dates and volumes exist in spreadsheets that are able to be bulk-loaded into the system. Finally, the IrriSat team has worked with third party agricultural service providers delivering scheduling advice based on methods other than

[17] For example, government: http://www.agriculture.gov.au/abares/monitor/commodities, private sector: http://www.awb.com.au/growers/awbgrainprices/esr & http://kochfertaustralia.com/

evaporation, such as soil moisture probes, that already collect irrigation and rainfall information in order to feed data captures into IrriSat without further manual effort from the farmer. So far, this approach has proved to be popular with farmers who claim to be "overloaded with apps, websites & information"[18].

System autonomy

After initial system release for full user access in September 2015, some refinements were made to assist users with data capture. Examples are, first, the ability for the system to accept uploads of Google Earth KML files[19] marking fields' boundaries, rather than requiring users to make them within the IrriSat UI only, and, second, to offer weatherstation data choices, rather than fixing weather data for all fields by referencing fields that are closest to the weatherstation.

Apart from these changes, little technical engineering work on the system has been needed and certainly none regarding day-to-day operations or system scaling. This is attributed to mature system design over many years' worth of iterations, and to the comprehensive laboratory testing over the 2014/15 cotton season by experienced aDSS staff and state departmental extension officers.

System cost

At the time of writing, GEE is free to use for "trusted users" and thus the project incurs no cost for using it. This is likely to change as GEE matures. Google App Engine (GAE) costs are free for small use and priced as per https://cloud.google.com/appengine/pricing for larger use. At this stage, IrriSat has mostly operated within the free quota but has just, at peak usage for several months, incurred a small cost of less than $AU100 per month to run.

Discussion

Addressing the inherited issues

When testing IrriSatSMS, the author was conscious of it being another technical aDSS that could easily fail to achieve widespread implementation due to reasons such as the inapplicability of scientific models to farming practice noted in papers such as McCown (2006) or the narrowness of 'technicentric' solutions to farm system management (Matthews, 2008). This was nevertheless believed to be worthwhile since the tool trial was not just attempting to leverage new technologies that enhanced the accuracy of the scientific models, such as field-scale crop coefficient readings from satellite imagery, but also technology that fundamentally changed the way the farmers could interact with the aDSS. The SMS messages used by IrriSatSMS really did work well with farmers' work patterns (Car et al., 2012) and we saw real promise in the system's future.

The failure of IrriSatSMS's commercialisation, described above, illustrates that ultimately issues other than the efficacy of IrriSatSMS as an aDSS contributed to its demise. When designing IrriSat, this knowledge was retained and thus IrriSat work didn't just look to improve aDSS technical capacity but also looked to directly address some of those reasons for its commercialisation failure. The technical and institutional arrangements listed in Tables 1 and 2 respectively make some good

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[18] Personal Communication with Montgomery, J. in April 2016. She is a New South Wales Department of Primary Industries extension officer conducting workshops on IrriSat usage with farmers.

[19] https://developers.google.com/kml/

inroads into addressing those failure reasons.

New challenges

Based on the good trial performance of IrriSatSMS and the deliberate attempt to overcome its commercialisation problems with IrriSat's design, the author feels that some amount of success is likely for the newer system. However, it is now clear from an understanding of the recent rate of farm usage change of technology relevant to IrriSatSMS & IrriSat, that what were once problems for farmers and agricultural service providers are no longer problems and that there are now new problems. The reason for dropping support for SMS in the new IrriSat – that farmers have smartphones, good Internet connectivity and familiarity with using them – has proved a boon regarding the reliance that can be placed on Australian farmers' ability to use advanced web-based UIs. It has also meant that farmers have become swamped with many competing decision support offerings and farmers, like people in other sectors of society, are facing a data deluge. Farmers' recent greatly enhanced connectivity, and the rapidly increasing array of interoperable local and remote data sources available to them, both add possibilities for IrriSat but also threaten its viability as users become overwhelmed with multiple information products competing for their attention.

One attempt that the IrriSat team have recently undertaken to address this issue is to integrate some part of IrriSat's decision advice into another information tool which is already used by cotton growers, a commercially-provided weatherstation and soil moisture probe system,. This is to reduce the number of systems they need to interact with daily (while responses to IrriSat's interface in the workshop sessions mentioned above were positive, workshop participants also indicated that they were "overloaded with apps, websites and information"[20]). This was not a complaint the author received from participants in the pre-2010 IrriSatSMS trials.

This author recalls a time, around 2007, when social network users were bombarded with calls from friends to join multiple social network sites - such as Bebo, MySpace, Friendster and Facebook - that each offered slightly different features to users. The sudden rise in popularity of these sites was due to increased internet connectivity among users (teenagers and young adults) and some technology changes making interactive web pages more usable. To use all of those different but competing social networks in parallel was not possible for most people and now, only Facebook retains large numbers of users. It is possible that potential users of IrriSat will see it competing directly with other systems for their attention, even if these other systems and IrriSat do not offer exactly the same features and that, ultimately, they may choose to use IrriSat or another system, but not both, due to the time commitments involved for effective use. This could mean that IrriSat is pitched against, perhaps, soil moisture probe systems, even though IrriSat's advice and that of the probes does not exactly conceptually overlap.

One aspect of Facebook's emergence as the winner of the social network competition is worth noting. Since its dominance, Facebook has added many new features and is now able, for instance, to support fan pages for music artists and home page customisations, which were once main features that MySpace had over its rivals. If IrriSat is out-competed for farmers' attention by an application not directly offering IrriSat's utility (that of locally customised, evapotranspiration-based waterbalance modelling that can enhance water use efficiency), it is possible that IrriSat's value offering may eventually be accreted by that other system. This is akin to the integration of IrriSat's advice into another tool, which was earlier mentioned as under trial. This mode of commercialisation was not explicitly indicated in Hornbuckle et al. (2009). The system design of

[20] Personal Communication with McIntosh, J. in March 2016, a New South Wales Department of Primary Industries extension officer working with IrriSat.

IrriSat is such that it would require very little effort on the IrriSat side for it to be integrated into another system's UI. This is because IrriSat makes use of APIs between system components, as described in relation to weather information in Figure 8.

Alternative pathways to on-going operations

In this paper I have already noted that, as part of the attempts to commercialise IrriSatSMS, a report was written aiming to detail "the conceptual framework and the practical elements that need to be assembled to make such a service operational" (Hornbuckle et al., 2009) and that it contained several potential commercialisation "Case Studies" outlining several ways IrriSatSMS could be provided to farmers in an on-going fashion. Several of those Case Studies considered pathways to ongoing IrriSatSMS use that did not rely on users of the system perceiving enough utility in the system for their own water-scheduling needs for them to pay subscription costs for its use. Several of the alternate pathways included on-going sponsorship by government, water supply institution or farmers' organisation for IrriSatSMS operational establishment and on-going costs, thus enabling free tool use for farmers. It was thought that such pathways would be viable given the obvious potential for those organisations to benefit from collecting field-scale farmer watering data in near real-time. This commercialisation pathway now being pursued for IrriSat via its CRDC sponsorship and is perhaps not new in the aDSS world and it is very much in line with the business models of many Internet 'apps' that are made freely available to end users in a strategy of harvesting their usage data for on-selling as the true product of the system. This strategy achieved some notoriety from around 2010 onwards and has been associated with the catch-cry of "If you are not paying for it, you're not the customer; you're the product being sold."[21]. By following this strategy for commercialisation, then, IrriSat's future custodians may need to work hard to convince end users that tool use is truly in their interests.

Conclusions

In this paper I have reflected on the failure of one aDSS commercialisation and related the design of its successor system to reduce the chances of future repeated commercialisation failure. I have also described the changing nature of the use of technology relevant to these aDSS on farms and the availability of relevant data.

Design choices were able to be made with the availability of new IT tools that have substantially reduced the risks involved for commercialisation partners in commercialising certain types of aDSS. Also, changes in technology use on farms substantially alter the environment in which aDSS of IrriSat's sort now operate and this means that some of the challenges faced by past systems are no longer relevant, even though new challenges have emerged.

Noting that some of the new challenges we believe face aDSS like IrriSat, such as similar systems competing for users' attention, have been encountered before in other non-agricultural fields, the author believes that IrriSat's ability to overcome some of those new challenges is as unknown to us now as the eventual success of Facebook was to everyone in 2008. As much flexibility, as possible, has been built into the IrriSat system in order to enable a number of deployment options which, it is hoped, positions it well for these new challenges.

The experience I report here points to a further challenge to overcoming "technicentric" approaches to commercialising innovations: significant and rapid changes in usage context imply that identifying

[21] Some of the first Internet chat to include this phrase is archived at http://www.metafilter.com/95152/Userdriven-discontent#3256046

the usage context, by using focus groups or representative farmers, is only a starting point. It is also necessary to track changes in the usage context as they occur and, further, to project changes to the value of innovation characteristics (and possibilities such as bundling of characteristics with other products) in ways that farmers probably cannot. The more substantial or prompt are related innovations, the more difficult will this tracking, and optimisation, of innovation value be, with implications for effective management of commercialisation.

References

Allen, R.G., Pereira, L.S., Raes, D. and Smith, M. (1998), *Crop evapotranspiration - Guidelines for computing crop water requirements*. Irrigation and Drainage paper 56, FAO, Rome. URL http://www.fao.org/docrep/X0490E/X0490E00.htm.

Australian Bureau of Statistics (2009), *Household Use of Information Technology, Australia, 2008-09*. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/8146.0Main+Features12008-09?OpenDocument. data cube: Excel spreadsheet, cat. no. 8146.0, 'Table 2 Households with home internet access, by period 1998 to 2008-09'.

Australian Bureau of Statistics (2011), *Household Use of Information Technology, Australia, 2010-11*. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/8146.0Main+Features12010-11?OpenDocument. data cube: Excel spreadsheet, cat. no. 8146.0, 'Table 1 Households with home internet access, by selected characteristics201011'.

Australian Bureau of Statistics (2014), *Household Use of Information Technology, Australia, 2012-13*. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/8146.0Main+Features12012-13?OpenDocument, data cube: Excel spreadsheet, cat. no. 8146.0, 'Table 4 Households with internet access, proportion of total households201213'.

Australian Bureau of Statistics (2016), *Household Use of Information Technology, Australia, 2014-15*. http://www.abs.gov.au/AUSSTATS/abs@.nsf/Lookup/8146.0Main+Features12014-15?OpenDocument, data cube: Excel spreadsheet, cat. no. 8146.0, 'Table 2 Households, by internet access at home201415'.

Australian Communications and Media Authority (2015), *Communications report 2014-15. Technical report*, Australian Communications and Media Authority, Canberra, ACT, Australia, URL http://www.acma.gov.au/theACMA/Library/Corporate-library/Corporate-publications/communications-report-2014-15.

Car, N.J., Christen, E.W., Hornbuckle, J.W. and Moore, G.A. (2012), 'Using a mobile phone Short Messaging Service (SMS) for irrigation scheduling in Australia: Farmers' participation and utility evaluation', *Computers and Electronics in Agriculture* 84, 132–143. doi:10.1016/j.compag.2012.03.003.

Carberry, P.S., Hochman, Z., McCown, R.L., Dalgliesh, N.P., Foale, M.A., Poulton, P.L., Hargreaves, J.N.G., Hargreaves, D.M.G., Cawthray, S., Hillcoat, N. and Robertson, M.J. (2002), 'The FARMSCAPE approach to decision support: farmers', advisers', researchers' monitoring, simulation, communication and performance evaluation', *Agricultural Systems* 74(1), 141–177.

CRC for Irrigation Futures (2010), *Annual Report 09-10. Technical report, CRC for Irrigation Futures*. URL (archived copy) http://pandora.nla.gov.au/pan/120721/20100712-1935/www.irrigationfutures.org.au/newsc1fe.ht ml?catID=5&ID=1058.

Hornbuckle, J.W. and Car, N.J. (2013), *Preliminary Research Proposal to the Cotton Research and Development Corporation*.

Hornbuckle, J.W., Car, N.J., Christen, E.W., Stein, T.M. and Williamson, B. (2009), *IrriSatSMS - Irrigation water management by satellite and SMS - A utilisation frame- work. Science Report 04/09*, CSIRO Land & Water, CSIRO Land and Water, Griffith, NSW, April. URL (archived copy) http://pandora.nla.gov.au/pan/120721/20100712-1935/www.irrigationfutures.org.au/news66b8.html?catID=9&ID=989.

Inman-Bamber, G. and Attard, S. (2005), *Inventory of Australian Software Tools for On Farm Water Management*, Technical report, CRC-IF.

Mackay, M.M. (2014), *Australian Mobile Phone Lifestyle Index: 10th Edition - Special Topic: Mobile Phone Use Compared To The Tablet And Personal Computer*, Technical report, AIMIA The Digital Industry Association of Australia, Sydney.

Matthews, K.B., Schwarz, G., Buchan, K., Rivington, M. and Miller, D. (2008), 'Wither agricultural DSS?', *Computers and Electronics in Agriculture* 61(2), 149–159.

McCown, R.L. (2002), 'Changing systems for supporting farmers' decisions: problems, paradigms, and prospects', *Agricultural Systems* 74(1), 179–220.

McCown, R.L. and Parton, K.A. (2006), 'Learning from the historical failure of farm management models to aid management practice. Part 2: Three systems approaches'. *Australian Journal of Agricultural Research* 57(2), 157– 172.

Montgomery, J., Hornbuckle, J.W., Hume, I. and Vleeshouwer, J. (2015), 'IrriSAT weather based scheduling and benchmarking technology', in T. Acuña, C. Moeller, D. Parsons and M. Harrison (eds), *Proceedings of the 17th Australian Agronomy Conference*, September, 1–4, Hobart, Tasmania. URL http://2015.agronomyconference.com/951.

Vleeshouwer, J., Car, N.J. and Hornbuckle, J.W. (2015), 'A Cotton Irrigator's Decision Support System and Benchmarking Tool Using National, Regional and Local Data', in Ralf Denzer, Robert M. Argent, Gerald Schimak and Jiří Hřebíček (eds), *Environmental Software Systems. Infrastructures, Services and Applications*, volume 448 of IFIP Advances in Information and Communication Technology, 187–195. Springer International Publishing. ISBN 978-3-319-15993-5. doi:10.1007/978-3-319-15994-2_18.

Walter, I.A., Allen, R.G., Elliott, R., Jensen, M.E., Itenfisu, D., Mecham, B., Howel, I.T.A., Snyder, R., Brown, P., Echings, S., Spofford, T., Hattendorf, M., Cuenca, R.H., Wright, J.L. and Martin, D. (2001), 'ASCE's Standardized Reference Evapotranspiration Equation', *Watershed Management and Operations Management,* 1–11, 2001. doi:10.1061/ 40499(2000)126.