Theme: Future technologies and implications for farm management

# DEVELOPMENT OF A COST-EFFECTIVE WATER PRODUCTIVITY ACCOUNTING TOOL FOR AGRICULTURE

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# DEVELOPMENT OF A COST-EFFECTIVE WATER PRODUCTIVITY ACCOUNTING TOOL FOR AGRICULTURE

**Abstract**

*Primary producers need strategies and tools to assist in monitoring water use with a view to improving physical and financial productivity. Farm accounting systems, if present, lack the sophistication to allow growers to analyse the use, loss and productivity of water to identify areas of potential water savings. Also, emerging farm technologies do not readily link to business systems to provide the optimal real-time financial decision making data. Findings of desk-based technology benchmarking suggest best-practice elements required include production 'hotspot' identification and real-time sensory data integration that allows for strategic allocation to all direct and indirect water use drivers. Key actor interview and producer demand surveys highlight demand exists for a cost-effective integrated water productivity tool, especially in regions where there is a large proportion of irrigated farming. The paper provides preliminary demonstration of how the crucial link can be made between producers' business systems and resource technology.*

**Keywords:** water accounting, water productivity, user-friendly technology, water accounting conceptual model

## 1. Introduction

Rising food demand and growing water scarcity are increasing pressure on agriculture, which uses about 70% of global fresh water for irrigation (UNIPCC 2007). A shortage of quality water for food production is a critical issue for the world's food and beverage producers (UNEP 2011). The agricultural sector is under increasing competitive and regulatory pressure to produce more with less and so requires urgent attention on accounting for water productivity to secure long-term profitability (Saseendran et al. 2015).

The accounting profession has been at the forefront of driving technical business tool adoption in agriculture, however there is acknowledgement that tools for costing water resource inputs are challenging to develop for the sector because of many factors (Jack 2009; Young and McColl 2009). Primary production comprises activities and processes which not only demand high water volume allocations, but also hide water usage and costs at various stages (Young and McColl 2009). Furthermore, the separation of water sources is difficult to account for which makes the direct assessment on water resource impacts challenging (FAO, 2017). Whilst there are currently macro and financial water accounting tools in development and use around the world (Young and McColl 2009; Hoekstra et al. 2011; Chalmers *et al.* 2012), these can be complex (Mulla 2013) or at the catchment or entitlement level (Jones and Thornton 2015), and do not link to producers' existing systems of water use information, or accounting systems (Hay and Pearce 2014). More is needed, especially at the farmer level, to set up specific and practical tools for implementation of accurate and complete water accounting for better understanding of food production costing (Hoekstra et al. 2011; UNEP, 2011; FAO, 2017).

The accounting profession also recognises the need for developing and implementing best practice water management (Hay and Pearce 2014). Accounting can be a catalyst for technological adoption on the farm which can lead to other improved processes (Brennan 2002; Chambers and Quiggin 2004). Hence, investigation into how accounting data and tools can support improved water productivity, lower risk, associated cost-savings and better water management for the largest freshwater user, agriculture, is of considerable relevance. Therefore, this paper seeks to answer the question: *How can a cost-effective integrated water productivity accounting tool be developed?* The following section details the methods employed for the research.

## 2. Methods

A mixed-methods data collection strategy was employed to capture a detailed review of publicly available water accounting and technological water information systems in addition to perceptions of key experts (Carmenta et al., 2011; Hochman & Carberry, 2011; Alcon et al., 2013).

- Phase 1 comprised a desk-based analysis of currently available water accounting frameworks and technologies to investigate the costs and benefits of implementation of the available programs. These were then comparatively analysed using publicly available data about the elements and their applicability to

Australian producers. This data was used to form a matrix of approaches and their positives and negatives for producers which facilitated benchmarking elements of better practice.

- Phase 2 included interviews with nine key experts in agriculture who had been identified publicly as being an 'expert' in agricultural sustainability and/or resource/water management. Interviewees included senior farmers, academics, industry body and government representatives. Interviews were face-to-face and undertaken at the participants' locations (i) to determine the necessary practical elements for water use productivity accounting, (ii) to discover meaningful patterns and (iii) how water and accounting elements (from Phase 1) should best be combined, structured and delivered to producers. Coding derivation of main themes was undertaken in NVivo and through combining these with the desk-based tool benchmarking results of Phase 1 enabled the development of a preliminary conceptual water productivity accounting tool.
- Phase 3 incorporates:
  - *Conceptual tool perceptions testing:* A producer demand survey to test perceptions about the potential cost-effective water productivity accounting tool, its potential ease-of-use and the best way for it to be applied. The target population was agricultural business owners or managers in South Australia (SA), Tasmania (Tas), New South Wales (NSW), and Victoria (VIC). Industry and regional strata were derived based on those (i) operating in industries known to require intensive water use and water storage (e.g. irrigated agriculture, dairy, etc), and (ii) operating in regions where water pressures whether through drought or flood or via stakeholders, were high (Pisaniello *et al.* 2012; Tingey-Holyoak 2014a; 2014b). The survey was conducted via mail with managers[1] with follow up phone-calls until the sampling frame was exhausted and an adequate response rate achieved. Basic statistics and non-parametric techniques were employed for data analysis and were conducted in IBM SPSS 21.
  - *Practical tool development:* currently in progress through case study of a potato crop in Walker Flat, South Australia approximately 104 kilometers from Adelaide. The center pivot irrigated site has been installed with two Sentek

[1] Managers or owners of agricultural businesses were chosen as the unit of analysis because they represent the organisation, and because they are often solely responsible for the organisation where it is likely that their views represent those of the entire business (Tingey-Holyoak & Pisaniello, 2015; Australia.gov.au 2011; NFF 2012).

D&D Triscan probes to 60cm and a remote weather station. Data collected from sensors include soil moisture, active rootzone depth, drainage, evopotranspiration, rainfall events and irrigation events. Data collected from farm accounting system includes water costs, pumping costs, fertiliser costs, cost of storage, maintenance, insurance, carting, labour and licensing. Data are currently being linked together using cluster analysis to determine key predictive relationships also linked to yield and quality outcomes.

Ethical approval for the above phases was obtained from the University of South Australia Human Research Ethics committee. The next sections present details and results of the four main phases of research.

**3. Results**

The following section will detail the findings of the desk-based comparative analysis of water and technical accounting tools, followed by results of key expert interviews which result in development of a preliminary conceptual model of a water productivity accounting tool. Finally, results of a producer demand survey are explored, including response to the conceptual tool, considering costs and benefits of such a tool to productionw.

**3.1 Current supply of water and technical accounting tools (Phase 1)**

There are a range of tools for water accounting globally, many of which are still under development and they have different strengths and weaknesses for application to the corporate sector (Bayart *et al*. 2010; CDP 2013). For this project, the relevance of tools to Australian agricultural producers is of specific importance and so included but was not limited to tools developed by Australian research and industry (Hochman & Carberry, 2011; ClimateKelpie, 2018). The Australian setting is unique for water accounting given the specific climate and ecological context (Vardon et al., 2007). Furthermore, agricultural production in Australia is often undertaken by many small scale producers who do not have access to accounting or technically trained support staff and equipment (Young & McColl, 2009; FAO, 2016). This is also compounded by a known ‘implementation problem’ for Australian agricultural decision support tools and so tools that cited on-the-ground delivery problems in multiple sources were excluded (McCown et al., 2009). Findings from comparative analysis of 10 well-developed tools that could potentially be applied in Australian agricultural production, showed that most lacked ease of use, and time saving capability and that they had a tendency to be too broad or externally focused, or not sophisticated enough to handle the methodological complexity of measuring water use efficiency in various production systems in different regions (Sultana et al. 2014). A summary of these findings is provided in Table 1.

Table 1. Spectrum of positive and negative elements of water accounting tools for agriculture

| | **Negatives** | **→** | **Positives** |
|---|---|---|---|
| Life Cycle Thinking Tools | Data too hard to access for producers | | IDs hotspots in production |
| Water Footprint Accounting | Time consuming Expensive | Can easily integrate into larger LCA framework | |
| Global Environmental Management Initiative Tools | Not user-friendly | LWT data integrates with large organisation external reporting systems | |
| World Business Council for Sustainable Development Global Water Tool | Not sensitized to the small primary producer level | | |
| Aqueduct | Macro level data | | |
| Aqua Gauge | Qualitative inputs time consuming | Quick and full versions | Excel based Benchmarking function |
| Veolia's Water Impact Index | Complex understanding of water systems required | Single output measure | Direct and indirect measures |
| Water Risk Filter | Risk assessment only | | User-friendly |
| Water Stewardship | Not sensitized to the small primary producer level | Links to other standards | |
| General Purpose Water Accounting | External focused | | |

It also became apparent that there is a lack of integration with or express recognition of the water information technologies that can assist producers achieve maximum productivity often at low cost. Irrigation and water use efficiency technologies also exist that help many producers. An in-depth review of 18 developed tools found that there was a lack of technical water information systems that are not only user-friendly and applicable at the farm level, but are inexpensive and can integrate into other business applications (Table 2).

Table 2. Technical water information systems review

| | **Negatives** | → | **Positives** |
|---|---|---|---|
| Yield Prophet | Grain production only<br>Historical weather data | Can be sensitized for climate change | Real time crop data during growing time |
| IrriStat-SMS | Limited regions in system | Benchmarking capability | Robust irrigation decision making<br>User-friendly |
| WaterSense | Sugar cane production only | Internet-based, no functionality without connection | |
| AQUAMAN | Peanut production only<br>Heavy farmer data inputs (daily) | Internet-based, no functionality without connection | Daily email report |
| Sense-T | Tasmania only | At this stage does not link to accounting/costing | Low cost<br>Real-time data<br>Spatial and historical data<br>User-friendly |
| IrriMate | Cumbersome | Specifically for water loss limits integration potential | |
| PIRSA Water Budgeting Tool | Needs other tools to support data requirement | Limited integration potential | |
| Consolidated Co-operative Wineries Variety and Water Priority | Riverland only | Limited integration potential | Simple to use spreadsheet |
| RESSTAT | Online survey<br>Point in time | Integrated socio-economic factors | |
| SWAGMAN | Complicated | Lacks economic underpinnings for suitable CBA | |
| Aquatech Watertrack | Potentially expensive<br>Point in time | Potential for daily data<br>Storage analysis as well as use | Benchmarking<br>Benefit/cost calculation |
| Sustainability Radar | Requires entire supply chain integration | | |

| | | | |
|---|---|---|---|
| EnviroVeg Platinum | Requires producer/retailer buy in | | |
| Irrigation Recording and Evaluation System | Horticultural production only Simplistic | | |
| Irrigation Performance Audit and Reporting Tool | Suitable for consultants, industry bodies etc rather than producers | | Crop, field and farm level spatial and temporal analysis |
| Water Manager | | Not available for specialty crops | Benchmarking and budgeting based on farm characteristics |
| CSIRO Water Use Efficiency Benchmarking | | Limited integration potential | Cost-effective and full versions |
| More Dollars Per Drop | Expensive Point in time | | In-depth assessment of technical requirements of property linked to economic objectives |

The water accounting tools and technical water information systems explored in this study are all fundamentally sound systems, but for producers, their application is not always straightforward. Therefore, for this study, their elements were benchmarked as per Table 3.

Table 3. Benchmarked elements

| | **Minimum-level element** → | **Best practice element** |
|---|---|---|
| **Water accounting tools** | Quantitative production metrics | Identifies hotspots in production |
| | Ease of access to entry data | Direct and indirect water-use data capture |
| | Quick and full versions | Data integrated across decision making systems |
| | Micro level farm applicable | Sensitized for farm size, especially small producers |
| | Internal in focus | Benchmarking |
| **Technical water information systems** | Sensitized to different prod types | Product-level sensory capability |
| | Regional sensitivity | Real-time farm/catchment weather data |
| | Easy to use | Integrates into other platforms including economic |
| | Cost-effective | Benchmarking |
| | Output easy to understand | Real-time data output in simple format |

The benchmarking revealed that water accounting tools and technical water information systems are usually separate and difficult to link. This in itself presents a further challenge to integrating all elements into a water costing tool that readily links with producers' business/accounting systems. Hence, the following key expert interviews were designed to assess current accounting systems currently in use by producers, reinforce and advance benchmarked water accounting and information elements above, and illuminate other factors that would be beneficial for a user-friendly water productivity accounting tool.

### 3.2 Interviews (Phase 2)

Nine face-to-face interviews, each of approximately 1 hour in length were undertaken in 2014/2015 with industry leading producers, consultants, policy makers and academics with publicly identifiable interest in agricultural business sustainability in South Eastern Australia (Table 4).

Table 4. Participant information

| Participant type | Type of business | Position | Number of employees |
|---|---|---|---|
| Industry leading producers | Vineyard and winery (TAS) | Viticulture Director | 15 |
| | Vegetable grower (VIC) | Director, Irrigation Manager | 5-50 |
| Key actor (industry) | Accounting firm (TAS) | Partner | 10 |
| | Agribusiness consultancy (TAS) | Principal | 5 |
| Key actor (academic) | Academic (TAS) | Professor | 5000 |
| Key actor (government) | Government (TAS) | Development Officer | 1000-3000 |
| | Government (VIC) | Policy Officer | 1000-3000 |
| Key actor (industry body) | Industry body (VIC) | Program manager | 50 |
| Key actor (natural resources agency) | Natural resources board (TAS) | Regional manager | 30 |

Participants were asked what kind of costing systems were commonly in use for primary production. Responses were varied with nearly half of respondents using or familiar with using MYOB (43%) and budgeting (43%) (Table 5).

Table 5. Monetary accounting systems

| Accounting system (monetary)* | % |
|---|---|
| Phoenix | 14 |
| MYOB | 43 |
| Excel | 14 |
| Employ accountant | 14 |
| Basic budgeting | 43 |
| Basic planning | 14 |
| Tax return only | 14 |
| Intrinsic knowledge | 14 |

**respondents could identify more than one system*

The Viticulture Director had an awareness of his business' need to use accounting tools to cost produce accurately: "...we are using MYOB as a budgeting tool and try to compare to actual figures. My financial controller says 'if you measure you can manage" (Viticulture Director). The other tools identified included Excel, tax returns and the use of a professional accountant (14%) (Table 5). Most interviewees indicated that formal accounting systems were pretty limited beyond Excel, however the accounting interviewee indicated that there were indeed clients who were operating a lot of MYOB, in addition to the more advanced Phoenix program.

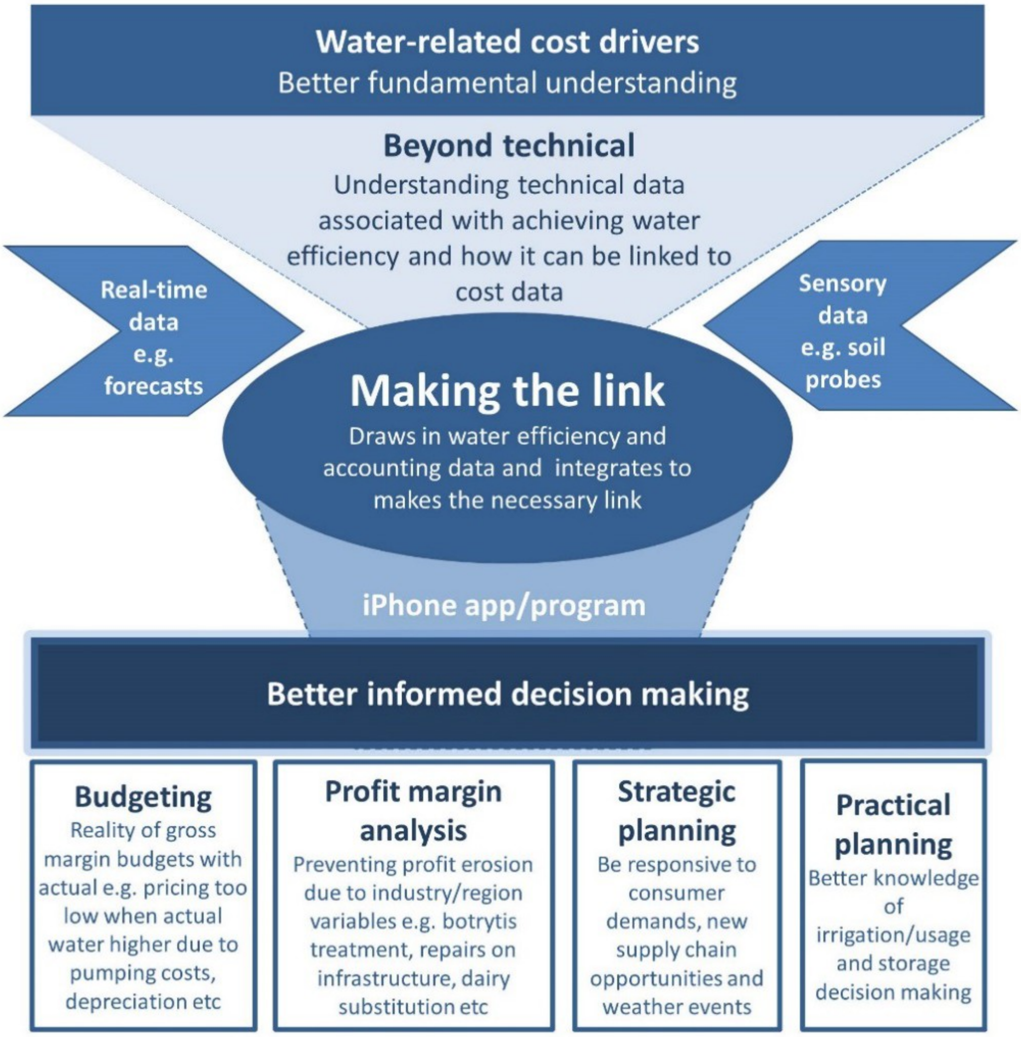
Most of the interviewees perceived that it would be very difficult to account for water throughout the whole of the production process. However, both leading producers indicated that they try to do it and plan to do it more in the future: "I differentiate water costs between different lines of products" (Irrigation Manager, Director), and, "I am trying to get to gross margin per block for the first time, but it is challenging to plan to capture everything [related to water]" (Viticulture Director).

The accounting interviewee perceived that accounting for water throughout the whole production process was possible but that "…..not currently happening with the systems and tools available" (Accounting Firm Partner). The agricultural consultant perceived that accounting for the cost of water throughout production was at present a challenge, but definitely possible with the correct integration of tools: "Many [producers] have sophisticated data collection systems on pivots etc. and more could be made of these to link with accounting systems as per your proposed tool idea" (Principal Agribusiness consultancy).

The interviewees considered elements that would need to be integrated to assist incorporating water technology into accounting systems. The wine producer "….would really like to see costs associated with my options to do different things at any given time given to me in a user friendly way, rather than having to go deeply into analysing it all myself which takes time." (Viticulture Director). The vegetable producer indicated fear of the risks associated with a water accounting tool: "We would rather spend 10% more up front and get perfect yield than save 10% on water and end up without 100% yield" (Director, Irrigation Manager) suggesting the importance of sensitizing such a tool for horticulture. However, the industry consultant provided context for how practically a tool could be of benefit for horticulture: "…it costs $2000/ML to store water in a dam versus $1100 to buy in, however the farmer thinks he could store water for $700, but they are not including the hidden costs of inspection every 3 years, doesn't fill every year, evaporation and so on….a water accounting system that takes hidden costs into account that helps profit margin analysis is needed" (Principal, Agribusiness consultancy). However, the lack of real time data has prevented take up of tools, supporting findings in Phase 1: "Real-time collection of water flow information is fundamental to take up and effectiveness of existing tools...Biggest [potential need for tool] are potatoes."

Whilst there was some divergence in opinions across the different types of interviewees, themes emerged that included the need for integration with real-time data and moving beyond the technical to better inform practical planning and profit margin analysis, especially in industries like potatoes. As a result of Phases 1 and 2, a conceptual model of an integrated water productivity accounting tool was developed for presentation to the Phase 3 survey participants (Figure 1).

Figure 1. Integrated water productivity accounting conceptual model




The model in Figure 1 demonstrates that in the first instance, on-farm water related cost drivers need to be identified and documented. Phase 2 demonstrated through management accounting tool investigation, reinforced by nine interviews that these drivers need to be better understood and integrated to ensure that all water-related costs can be factored into production decision making. This then needs to be combined with the increasing sources and amounts of sensory data, much of which are of limited use to farmers without integration with their business planning and processes. Interviewees advised that the link to actual accounting, which needs to be made through development or collaboration with a software provider, ultimately must result in a low-cost, user-friendly interface, either in app or cloud format. This leads to the foundations for better informed decision making required from this tool, including for budgeting, profit margin analysis and planning. A particular example could be preventing profit erosion caused by industry/regional variables such as required crop disease treatment, repairs on infrastructure damaged by weather events. The following section presents results of surveys of producers presented with the model and their demand and need for such a tool explored.

### 3.3 Producer testing (Phase 3)

Conceptual tool demand surveys. In order to understand producers' receptiveness to water productivity accounting, a survey was undertaken with 110 producers where they were presented with the preliminary model (Figure 1). The surveys took 20 minutes each and no incentive was offered for participation. Participants were asked how they were currently costing their produce and over one third had no formal method of produce costing (35%) with no statistically significant difference between the states ($X^2$=33.58, $p$=0.09) (Table 6). If a method was identified, then it was usually undocumented (17%) or a part of planning (15%). Notable is that despite this apparent lack of sophistication of management accounting systems for produce, the sophisticated agricultural accounting system Phoenix is in use in all states in Australia, most commonly in South Australia (26%) where there is also the highest use of MYOB across the four states (11%) (Table 6).

Table 6. Producer produce general costing methods and water costing perception

| | SA (%) | NSW (%) | Vic (%) | Tas (%) | Total (%) | Chi-Squared |
|---|---|---|---|---|---|---|
| No costing methods | 21 | 70 | 30 | 38 | 35 | $X^2$=33.58, $p$=0.09 |
| Undocumented costing methods | 5 | 0 | 18 | 25 | 17 | |
| Costing part of budgeting/planning | 21 | 0 | 18 | 15 | 15 | |
| Phoenix costing | 26 | 20 | 25 | 8 | 18 | |
| Excel costing | 11 | 0 | 3 | 10 | 7 | |
| Handwritten costing methods | 5 | 10 | 3 | 4 | 5 | |
| MYOB costing | 11 | 0 | 3 | 0 | 3 | |
| Specific water costing/accounting | 31 | 0 | 31 | 13 | 27 | $X^2$=12.84, $p$=0.38 |

**=sig.@p<0.05, **=sig.@p<0.01, ***=sig.@p<0.001*

As noted in Table 6, participants were asked if they currently link the cost of their water to the cost of their produce. Across the sample, only around one quarter of producer respondents are currently costing their water into their produce in some way (27%). The difference between states was not significant however it is notable that no New South Wales producers indicate they are undertaking linked water accounting/costing.

Nearly two thirds of respondents perceived that the tool presented would be useful or very useful (59%) with only 13% perceiving that it would not be useful to their business. There was no statistically significant difference between states ($X^2$=13.42, $p$=0.34), however the tool was perceived to be most useful in Tasmania (64%) followed by South Australia (62%), and Victoria (60%) with New South Wales respondents the least likely to find the tool of use (30%). This parallels the results in Table 6 with New South Wales respondents also least likely to be undertaking water accounting. Open-ended comments included much general support for the concept, such as:

- *"…good summation of the information required in order to make decisions re water usage"* (Tas Farmer)
- *"…the tool has covered what is required to analyse my costs"* (SA Farmer)
- *"…simple to understand"* (Tas Farmer)

However, ease of data gathering, reduced complexity and applicability to smaller farming businesses were identified as factors in its success, for example:

- *"…my request would be to keep it 'user friendly' and not too much data analysis"*
- *"…a promising start - I would like further refinements and relationships established, e.g. methods of irrigation and specific measures for comparison*"

Furthermore, despite the 'cost-effective' premise behind the conceptual model, cost of the tool was still a concerning factor:

- "…[useful tool but] *worried about the charge that would come along with it*" (Tas Farmer)

Respondents were asked to consider what improvements such an integrated water management accounting tool could make to their farming business. Over third of respondents indicated that the tool would improve their profitability (34%), with no statistically significant difference between states ($X^2$=6.86, p=0.87) but the highest perceptions from South Australia and Victoria (37%) and Tasmania (32%) and the lowest from New South Wales (20%) (Table 7).

Table 7. Perceived business improvements from tool

| | SA (%) | NSW (%) | Vic (%) | Tas (%) | Total (%) | Chi-Squared |
|---|---|---|---|---|---|---|
| Improved profitability | 37 | 20 | 37 | 32 | 34 | $X^2$=6.86, $p$=0.87 |
| Improved competitiveness | 52 | 0 | 27 | 25 | 25 | $X^2$=10.88, $p$=0.54 |
| Improved environmental impact | 32 | 0 | 31 | 34 | 30 | $X^2$=13.61, $p$=0.33 |
| Improved customer communication | 27 | 20 | 37 | 22 | 27 | $X^2$=4.76, $p$=0.97 |
| Improved regulator communication | 42 | 20 | 46 | 54 | 52 | $X^2$=11.93, $p$=0.45 |
| Improved bank communication | 27 | 0 | 21 | 9 | 10 | $X^2$=8.95, $p$=0.71 |
| Improved product design and labelling | 11 | 0 | 14 | 16 | 13 | $X^2$=16.71, $p$=0.34 |
| Improved worker satisfaction | 32 | 0 | 46 | 26 | 25 | $X^2$=17.78, $p$=0.28 |

**=sig.@p<0.05, **=sig.@p<0.01, ***=sig.@p<0.001*

Around a quarter thought their competitiveness would improve (25%) and a third that their environmental impact would be improved. Whilst these responses are not in the majority, the finding indicates enough potential scope for advancing the tool to a demonstrable platform, such as through field development and testing to highlight the specific links to business data and make integration with accounting data more visible. Interestingly, this is further supported by the most perceived potential business improvements being found to be in improving regulator communication (52%), highest in Tasmania (54%) which highlights the need for water accounting tools that can discharge accountability to regulators as part of usual business processes without additional data gathering or communications. Most respondents did <u>not</u> think the tool would assist them with communicating their water information with the bank (90%), nor would it be helpful with product design/labelling (87%). However, a quarter did agree that such a tool might improve worker satisfaction (25%), highest in Victoria where nearly half of producers surveyed (46%) agreed the tool would be beneficial in this way.

The most preferred technology for the tool was an iPhone or iPad application (44%) followed by Excel (24%) and then a PC (general) (21%) (Table 8) suggesting that increasingly producers require technology that they can access in the field across multiple platforms.

Table 8. Preferred platform for integrated water productivity accounting tool

| Platform | % |
|---|---|
| iOS App | 44 |
| PC | 21 |
| Excel | 24 |
| Android App | 3 |
| Filemaker | 3 |
| MYOB integrated | 3 |
| Specialised agribusiness software | 3 |
| Mac | 3 |
| Cloud | 3 |

**respondents could choose more than one option*

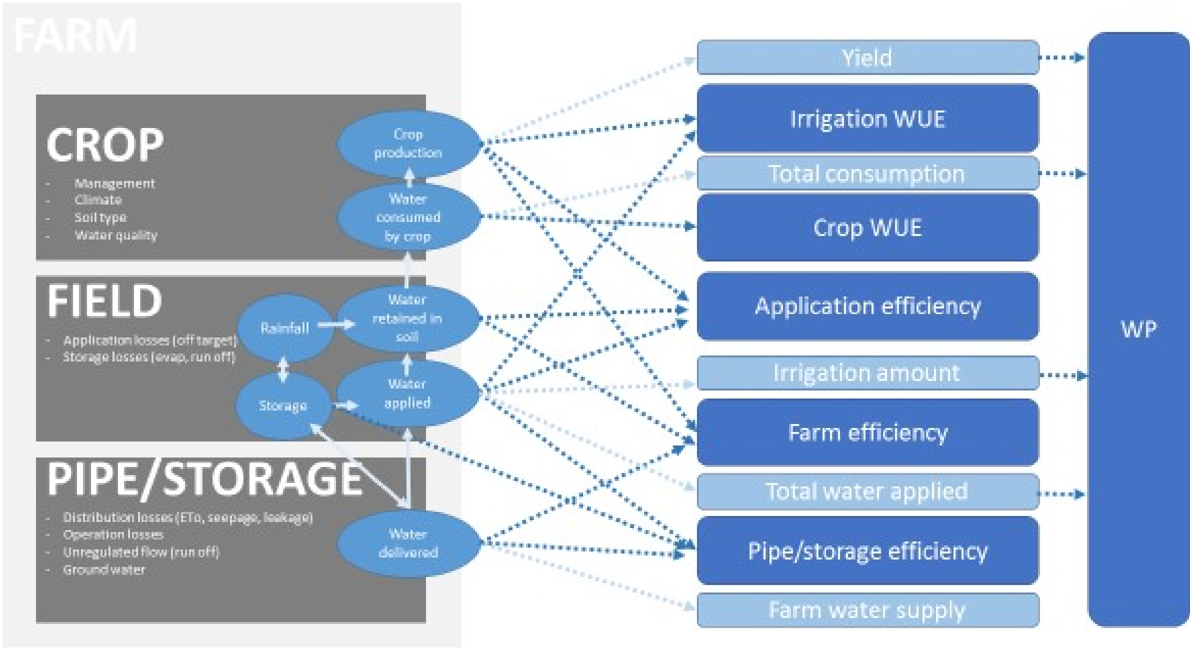
*Practical tool field development (in progress).* In light of the producer survey results, a Walker Flat potato site was installed with soil moisture probes and a weather station. Monitoring of the water content with Triscan 60cm probes within the soil profile has been proven to help growers make better informed decisions regarding aspects of crop growth under their direct control. So far these have not been integrated with financial data to help growers develop management strategies to reduce their level of risk and make savings wherever possible which is the purpose of this phase of the project. The 28 Ha site was located on sandy soil and ran two potato varieties for 97 days from mid-March 2018 to end of June 2018. The farmer is not currently undertaking any form of water accounting. Data gathered included that from the Soil-Water-Plant-Atmosphere continuum as per Figure 3. On farm accounting data has also been captured including all possible water related costs from farm accounting software, formal and informal records and grower diarized records and accounts (Table 9). The accounting data are require inputs to derive the conceptual model output elements of budgeting, profit margin analysis, strategic planning and practical planning.

Table 9. Water related accounting data

| | Item | Description of item, examples etc |
|---|---|---|
| **Budgeting** | Electricity costs per hour | To give pumping costs – broken down to pump for this crop only if possible but if not that is ok and will just need to know how many fields/crops the pump was servicing and work back |
| | Water cost | Cost of water applied to crop |
| | Cost of total fertilizer applied | Total cost |
| | Hourly rate of irrigation labour | Time spent on water related activities at that field – your hourly rate and that of those who helped, including any external contractors |
| | Carting fees | Eg any moving of actual water around the property related to this crop in tanks |
| | Insurance costs | Eg insurance for pivots (and pipes, storage etc if relevant) p.a. |
| | Cost of storage | Any costs involved in storing water for this crop in dams/tanks and details. |
| | Cost of repairs | Any water infrastructure repairs during period or during set up for this crop |
| | Cost of maintenance | Eg broken pipes etc.Any water infrastructure maintenance/upgrades during period or during set up for this crop |
| | Depreciation per year on pivot / pipes / equip used in field | Can calculate this simple straight line (cost $ / useful life yrs = 2018 deprec) |
| | Water licensing / allocation fees/charges | Eg Internal or external admin costs, liaising with department, contracting, consultants, legal fees etc |
| **Practical planning** | Field size | Size of area where sensed potato crop grown |
| | Total property size | To give scale to any farm-wide bills/amounts |
| | Amount of total fertilizer applied | It would be great to have a total in addition to any variability over the season– eg approximate days which were high fertilizer application |
| | ML applied | Actual application to this crop in total |
| | Days ML applied | Actual application to crop if known from pivot/day for 1 Feb – 1 Aug |
| **Strategic planning** | Hours pumped each day 1/2/18 – 1/8/18 | This will be variable depending on day –pivot provides an output |
| | Hours spent on irrigation per day on site *set up* pre-1 Feb | Eg setting up pivot, new pipe installation, channel construction, pump set up etc |
| | Hours spent on irrigation labour/day 1 Feb-1 Aug | Eg moving pivots etc |
| | Quality data | Quality of produce |
| | Comparative data | Eg virgin soil improved output, reduced fert use etc. |
| **Profit margin analysis** | Yield data | Tonnes and $ |

Data will then be used to make sense of the economic condition of the crop, field and pipe/storage levels (Figure 4) including application and farm efficiency.

Figure 4. Economic relationships




Analysis of relationships between data sources is being undertaken at present including deration of relationships between data sets and initial dimension reduction - the full set of results are forthcoming in a future paper. However, preliminary data shows that as expected, fertilizer and power costs have a direct relationship to the timing of irrigation events and increased awareness of optimal pumping time and hours provided by the tool will be of benefit to growers. Farmer decision making has been effected with multiple reported irrigation events cancelled or rescheduled based on information from real-time sensing about water logging in soils. This has created savings in water and pumping costs which has improved productivity and likely profitability for the quarter. Despite only around a third of farmers perceiving the tool could improve their competitiveness, it is likely that this will be the main effect of the tool, rather than as a device to discharge regulator accountability (Section 3.3). Furthermore, preliminary results indicate that making transparent the hidden costs related to water including labour, depreciation, and maintenance will have significant impacts on decision making. The exclusion of these costs from grower decision making tools could be resulting in significant profit erosion however data is currently in analysis and being fed into the development of a preliminary software tool by researchers at University of South Australia's Advanced Computing Research Centre with results forthcoming.

## 4. Discussion and implications

Many organisations have started to respond to water risk, are measuring their water consumption and reducing it, as well as sharing water-related information with regulators and other stakeholders. However, the necessary internal organisational focus on water management such as that provided by a water productivity accounting system has not yet emerged. This study aimed to investigate the potential and demand for a user-friendly water accounting tool for agricultural producers.

In *Phase 1*, a review of standardized tools and methods for water accounting and technical water use efficiency systems facilitated advancement of knowledge of the best-practice elements that could possibly be linked to accounting systems. Results find that any tool needs to be able to be sensitised for smaller producers in addition to the need for increased crop and farm level sensory and real-time data functionality in addition to being user-friendly and integrate with other decision making systems. Findings from ground-water accounting research also find that consolidating both crop and farm level information for assessment and interpretation is critical for water accounting tools to be successful, and in order to develop an information resource that is accepted by other stakeholders, such as regulators (Foster et al., 2009; Foster & Perry, 2010).

*Phase 2* key expert interviews also reveal that tools need to be tailorable for different water related costs for different purposes and importantly able to capture both indirect and direct water-related costs. Such a tool would also need to be cost-effective yet able to fully integrate water accounting technology and financial accounts utilising timely spatial and temporal data to facilitate practical planning. This is supported by global research which finds that evidence informed decision making is crucial to any success of water accounting (FAO, 2017). This is even more so the case in areas like California where prompt decision making base on sensed water data is critical for effective response on both water quantity and quality aspects (Shilling et al., 2005; Meals et al., 2010).

*Phase 3* producer demand data from the farmer survey indicates that whilst many farmers perceive they are costing in their water, there are many informal systems of accounting and costing being used that would be challenging to link accurately to technical water information. Furthermore, most producers are not currently costing in their water. Whilst many participants see the potential of the tool for their competitiveness and profitability, the strongest business benefit was perceived to be to discharge accountability to regulators, reinforcing that regulatory pressure is one of the greatest pressures on agricultural business water use and storage at the moment, especially in Tasmania, and the need to simplify and possibly integrate data collection and communications. Furthermore, many producers see the benefit of such a a tool for their employees, further reinforcing the potential of such a tool to reduce farmer time spent on collecting and communicating produce data. Whilst the business benefits of the tool for food labelling or bank communications were not strongly perceived, given recent food labelling regulatory changes and ecolabelling discussions in Australia (Tan 2013; Bourke 2015) and also moves in Europe toward water labels on food (Segal & MacMillan, 2009), the percentage of producers interested in tools to assist with labelling information could increase in the not too distant future. Furthermore, with the big four banks in Australia moving to focus on accounting for natural capital to secure finance and negotiate lower interest rates (Yeates 2015; Goodwin, 2017) attention to possible user-friendly natural resource accounting tools will likely increase.

Besides the *conceptual* tool's potential benefits to producers in discharging regulator or financial accountability, recent international research highlights that improved decision making is not possible if such tools and technological advances do not translate to actual on-the-ground productivity improvements (Green, 2011; Gleick et al., 2011). The producer survey revealed that there are largely informal mechanisms for accounting and produce costing on most farms, many of which ignore hidden or indirect costs meaning that profitability could be eroded. Therefore there is potential for the tool to make transparent hidden water-related costs which has recently been noted as a critical problem globally (FAO, 2017).

The preliminary data emerging from development of the *practical* tool on a potato case study site has further highlighted the need for inclusion of all costs to be integrated with sensing data for producer decision making. This especially includes the indirect and often hidden costs of pivot depreciation and labour which when specifically calculated up over a growing period can be substantial, especially for farmers who do not ordinarily cost out their time spend on irrigation equipment and other water-related management. Simply and cost-effectively tracking this data is central to any type of water accounting (FAO, 2017). Triscan probes have been showcased internationally as an economically viable way to increase agricultural sustainability (Pardossi et al., 2015) and when data is integrated with accounting data as reported here, these sensors show great potential for useful and easy to use inputs. Farmers surveyed identify iOS application output format based out of a 'module' of a current accounting program as most useful for them. Work on producing the prototype for this is currently underway at UniSA based on emerging potato data.

**5. Conclusion**

This paper investigates the potential and demand for an innovative, cost-effective water productivity accounting tool and develops preliminary guidance on its development and field testing in potatoes. Through answering the question: *How can a cost-effective integrated water productivity accounting tool be developed?* the research found that there is a need for water information to be simply and cost-effectively drawn into accounting systems requiring the ability to identify water hotspots in production, product and farm/region benchmarking, real-time and sensory data integration, strategic identification of direct and indirect water use drivers, and above all a user-friendly application.

What this means for policy makers is that producers are likely be receptive to a tool to better account for their water as long as it has clearly communicated benefits. However, it is important to note that the benefits whilst focused on farmer productivity and profitability, will also result in broader catchment-wide water savings especially if broad adoption is promoted. Such a tool in use could serve to meet policy objectives of both sustainable regional communities' agencies and water resources management agencies which are often not integrated. Limitations of the study include examination of perceptions of key actors and producers in only four states in Australia, based on cross-sectional data which requires caution when generalising broadly to real world problems, typically with a long life-span. Furthermore, the emerging findings of application in potatoes are only preliminary and are set to be replicated in a subsequent growing season in early 2019, and the research team are currently undertaking a viticulture case study due for completion in July 2019 – both of which will allow for a longer term understanding of outcomes from such a tool. Technical application is also underway using data being analysed from on-site case studies.

Ultimately, how farm accounting systems can be linked to benchmarked elements for water accounting in a user-friendly water productivity accounting tool, and how the tool can easily be applied by producers, is of great significance to both the accounting and primary production sectors. This paper serves to form a crucial foundation for continued research whilst advancing understanding about how user-friendly tools for integrated water accounting and management can and should be integrated into farming businesses.

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