FARMERS AS WATER MANAGERS

Local interventions, personal preferences, and system-level implications

Melle Nikkels

Propositions

1. A single workshop can foster social learning.
   (this thesis)

2. Participatory water valuation is not about money.

   (this thesis)

3. The current Dutch transition towards circular agriculture needs to focus on deliberative dialogue.

4. Easy decisions can be calculated, complex decisions also require intuition.

5. Besides money and rules, policymakers have coffee as an instrument to govern wicked problems.

6. Learning is intrinsically desirable, even without tangible outcomes.

7. Researchers' personality, gender and background influence both the research process and outcomes.

8. A PhD candidate can relate to Frodo in The Lord of the Rings: You may have helpers but you carry the "precious" yourself.

Propositions belonging to the thesis, entitled

Farmers as water managers: Local interventions, personal preferences, and system-level implications

Melle J. Nikkels

Wageningen, 20 May 2020

Farmers as water managers

local interventions, personal preferences, and system-level implications

Melle Jochem Nikkels

Thesis committee

Promotors

Prof. Dr Petra Hellegers
Professor of Water Resources Management
Wageningen University & Research

Prof. Dr Holger Meinke
Strategic Research Professor, Global Food Sustainability
University of Tasmania, Australia

Co-promotors

Dr Pieter van Oel
Associate professor, Water Resources Management Group
Wageningen University & Research

Dr Peat Leith
Senior Research Fellow, Tasmanian Institute of Agriculture
University of Tasmania, Australia

Other members

Prof. Dr Arjen Wals, Wageningen University & Research
Prof. Dr Pieter van der Zaag, IHE Delft Institute for Water Education
Prof. Dr Dave Huitema, Vrije Universiteit Amsterdam
Dr Geeske Scholz, Osnabrück University, Germany

This research was conducted under the auspices of the Graduate School for Socio-Economic and Natural Sciences of the Environment (SENSE).

Farmers as water managers

local interventions, personal preferences, and system-level implications

Melle Jochem Nikkels

Thesis

submitted in fulfilment of the requirements for the degree of doctor

at Wageningen University

by the authority of the Rector Magnificus,

Prof. Dr A.P.J. Mol,

in the presence of the

Thesis Committee appointed by the Academic Board

to be defended in public

on Wednesday 20 May 2020

at 1:30 p.m. in the Aula

Melle Jochem Nikkels

Farmers as water managers: Local interventions, personal preferences, and system-level implications,

234 pages.

PhD thesis, Wageningen University, Wageningen, the Netherlands (2020)

With references, with summaries in English and Dutch

ISBN 978-94-6395-386-3

DOI https://doi.org/10.18174/520352

TABLE OF CONTENTS

1. INTRODUCTION

1.1. BACKGROUND

Water shortage remains a key constraint to agricultural production in many countries, despite large-scale investments in irrigation infrastructure during the 20th century (de Fraiture et al., 2013). Water shortage affects local and global economies, and communities as well as farmers (Lipton et al., 2003). Farmers can influence their water availability through on-farm soil and water management and investment decisions, such as construction of on-farm water storage or the purchase of water licences (where such options exist). These kinds of on-farm interventions provide a means to mitigate rainfall variability, as water can be stored when it is abundant for irrigation usage later (Nathan & Lowe, 2012; Zuurbier et al., 2017). On-farm interventions can thus contribute to agricultural production and farmer livelihoods.

Beyond the local benefits gained by farmers, private interventions impact the wider hydrological system in which farmers operate. A hydrological system spans a particular geographical region dependent on one or more water sources (Thissen et al., 2015). These systems might be a polder, a catchment, or an irrigation scheme. Local interventions have system-level implications, as they influence water availability at different locations and times, through effects on peak flows, base flows, and overall water resource distribution (Habets et al., 2018). Local interventions can alleviate pressure on governments to invest in large-scale infrastructure, such as reservoirs and flood mitigation measures. Although this is generally acknowledged, adequate tools to quantitatively assess farmers' influence on the wider hydrological system are not readily available. Because the precise and diverse regional implications of local interventions are poorly understood, they are hardly accounted for in decision-making (Grafton et al., 2018; van der Zaag & Gupta, 2008). Unknowns regarding the cumulative effects of local interventions need to be addressed to adequately inform water governance actors, including farmers, water managers, and policymakers. Currently, these unknowns hamper assessments of how farmers potentially can, and already do, influence regional water systems (ZON & DHZ, 2015).

To better understand farmers' influence on the regional water system requires approaches that go beyond local or regional hydrology. For instance, interventions may require substantial investment such as installing on-farm infrastructure. Long-term regional water management plans increasingly depend on farmers' decisions to invest in on-farm infrastructure and/or water use licences (Gleick, 2003; Turral et al., 2010; Ward, 2010). Hence, a complete assessment of farmers' influence on the regional water system requires a better understanding of farmers' investment decisions in (additional) water for irrigation (van Duinen et al., 2015).

When farmers consider co-investing with (local) government, they need relevant information to help them decide whether an outlay for one or multiple alternative water sources is "worth it". What "worth it" means is typically personal, subject to change, and often difficult to quantify. For some the focus might be monetary, i.e., financial costs and expected benefits, while for others intrinsic motivations may be more prominent, such as desire to be a responsible land steward (see e.g. Šūmane et al. (2018); Vanclay (2004)). Providing relevant information therefore requires a broad understanding of farmers' personal preferences regarding water sources and their considerations in decision-making (Pahl-Wostl et al., 2008a; Wutich et al., 2014). Reasonings and preferences may vary for multiple reasons, such as heterogeneity of local circumstances and situations, real and perceived uncertainties, perceptions of the value of water for irrigation, and knowledge and insights gained through previous experience.

Exploring one's own objectives and reasonings and comparing these with others' can be meaningful for farmers, as it can help build their confidence and capacity to make better-informed decisions (Kenter et al., 2016a). Such an exploration might also point to ways to overcome challenges in anticipating farmers' preferences regarding water sources and to clarify why farmers may decide to invest (or not to invest) in local interventions.

Despite a lack of understanding of the cumulative effects of local interventions on the water system as a whole, and limitations in providing relevant information to help farmers with their investment decisions, (local) governments are increasingly calling upon farmers to join in efforts to achieve long-term regional water system objectives. This idea of "farmers as water managers" acknowledges the impact of on-farm interventions on long-term water management agendas (e.g. AgriGrowth Tasmania, 2017; LTO Netherlands, 2019; Ministry of Infrastructure & Environment (I&M) & Ministry of Economic Affairs (EZ), 2014). Long-term objectives differ between countries and even from region to region; with such differences particularly reflective of agricultural policies. For example, in 2014, the state government of Tasmania, Australia, set the long-term objective of a tenfold increase in agricultural production value by 2050 (AgriGrowth Tasmania, 2017; Tasmanian Liberals, 2018). To enable such substantial growth in production value, expansion of irrigated agriculture will be essential. This means that non-irrigators will have to change their production practices and become irrigators (Tasmanian Irrigation, 2012a).

Another example of a longer-term water system objective is seen in the Netherlands, where the Dutch Delta programme aims to maintain a safe and attractive water system by providing adequate flood risk management and freshwater supply (Van Alphen, 2016). Farmers are therefore being asked to cooperate with regional water managers and policymakers to improve the "sponge capacity" of regional water systems. Greater local buffering capacity would reduce peak flows, and retained water could be used in dry seasons to help overcome water shortages (ZON & DHZ, 2015).

To achieve such long-term objectives under variable economic and climatic conditions, strategic and adaptive decision-making is imperative (Garrick et al., 2017; Meinke et al., 2009; Walker et al., 2013). However, decisions that lead to changes in the water system affect all who are tied to it (Boelens et al., 2016; Lane, 2014). For instance, access to additional or stored water for irrigation may lead to (desired) changes in farm operations, which impact the life of the farmer and his/her family. Therefore, water systems cannot be defined only in biophysical terms; hydrological systems are both natural and social, shaped by the coupled dynamics of human-water interactions

(Falkenmark, 1977; McMillan et al., 2016). The notion that human systems and water systems co-evolve over space and time in a dynamic process is explored in the literature on human-water interactions (Linton & Budds, 2014; Wesselink et al., 2017). Yet, unknowns and ambiguity in both the hydrologic and social domains continue to challenge the design and management of adaptive water systems (Melsen et al., 2018; Srinivasan et al., 2017). These unknowns and ambiguities call for an iterative and ongoing "learning-by-doing" approach (Pahl-Wostl et al., 2007a; Pahl-Wostl et al., 2007b; Savenije et al., 2014).

Policymakers, water managers, and farmers often fail to realize that preferences, knowledge, and understanding will change over time. Acknowledging these complex dynamics raises water management and governance challenges that need to be explicitly addressed to achieve system-level objectives. For sound investment decisions on infrastructure, without later regrets (see Lawrence and Haasnoot (2017) for an example on flood protection), we need to better understand the influence that farmers, today and in the future, can have on regional water systems, while acknowledging that water and society make and remake each other over space and time in a hydro-social cycle.

1.2. PROBLEM STATEMENT

Recognizing that assessing how farmers can and do influence regional water systems requires approaches that go beyond a focus on local or regional hydrology, this study addresses five knowledge gaps spanning the hydrological and social domains. Bridging these gaps can help us adequately understand the role that current and future farmers (can) play in regional water management.

The first knowledge gap is the well-known difficulty in assessing how on-farm interventions will influence regional water systems, as the cumulative effects of such interventions are non-linear and difficult to predict (van der Zaag & Gupta, 2008). Many previous studies have treated the spatial and temporal effects of a set of (desired) interventions as outside their research scope (e.g. Habets et al., 2018; Lasage & Verburg, 2015; McCartney et al., 2013; Pandey et al., 2011; Van Meter et al., 2016). Yet, obtaining a clear overview of the challenges involved in assessing the regional-level impact of, for example, local water storage is an important first step to adequately inform decision makers on the local and regional effects of on-farm interventions in the water system.

Second, it is as yet unclear why farmers make the decisions they do regarding strategies to gain access to additional water volumes. For instance, if multiple irrigation water sources are available, farmers often exhibit a clear preference for a particular alternative. There is ample empirical evidence, however, that these preferences are not uniform across a group of farmers (see e.g. van Duinen et al., 2016; Veraart et al., 2017). This is in line with Raworth's (2017) perspective on economics in the 21st century. Farmers base their choices on individual logics, which limits the ability of others to anticipate investment decisions. This suggests the need to better understand the personal reasonings that underlie farmers' preferences. To gain this understanding, we must go beyond "what can be counted" and focus on "what counts" instead (Vanclay, 2004). However, evaluation tools and approaches that empirically capture what farmers care about when comparing alternatives are as yet lacking.

This leads to a third, related knowledge gap in the personal valuation of irrigation water. Current evaluation approaches are unable to capture the personal reasoning that underlies decisions to invest (or not to invest) in irrigation water. Valuation of water for agriculture is known to be challenging. Numerous authors have argued that the current approaches for valuating water for irrigation are biased or incomplete (e.g. Birol et al., 2006; Davidson et al., 2019; Turner et al., 2004). Capturing personal reasonings could elicit a broader set of (non-monetary) values and contribute to a better understanding of the assumptions and personal reasons that underlie these values. To provide information that is relevant and enable farmers to make informed decisions, existing valuation approaches need to be complemented with participatory methods that dig deeper into the assumptions and personal considerations that underlie farmers' valuations of additional volumes of irrigation water (Hermans et al., 2006a). Looking into farmers' considerations responds to the calls of World Bank (2017) and Garrick et al. (2017) for water valuation methods that address the multiple and personal values of water.

The fourth knowledge gap regards the potential of water valuation as a tool to foster social learning. There is a lack of agreement on what constitutes social learning, how it can be facilitated, and how outcomes can be assessed (Rodela, 2011; Wehn et al., 2018). This has hampered development and evaluation of social learning processes (Reed et al., 2010). Moreover, empirical assessments of social learning have as yet been few and limited in scope (Gerlak et al., 2018; Scholz et al., 2014a). There seems to be more agreement on the purpose of social learning: learning together to better manage and govern together (Pahl-Wostl, 2017). Better understanding of the factors contributing to, and the outcomes of, social learning processes could promote the uptake, funding, and acknowledgement of social learning.

Finally, human-water dynamics are not adequately considered in the management of many water systems. Though farmers may contribute and co-invest at one stage, the needs and preferences of generations to come are rarely sufficiently explored or considered (see e.g. Australian Government (2015). However, water systems face unforeseeable changes in climate, technologies, and societal preferences, which could render them prematurely obsolete or inadequate (Haasnoot et al., 2013; Offermans & Valkering, 2016). This can lead to sub-optimal investment decisions that are regretted later and even restrict the role of future farmers as water managers. Designing and managing water systems that are adaptable to unforeseen changes and open to learning-by-doing is a challenge that has yet been largely unmet (Lane, 2014).

1.3. OBJECTIVES AND RESEARCH QUESTIONS

This thesis thus addresses challenges in assessing farmers' influence on regional water systems. The objective is to develop approaches to improve our understanding of farmers' current and potential contributions towards long-term objectives for regional water systems. The research is organized around the five knowledge gaps identified above. As farmers' considerations are ultimately personal, this research sought to learn from and with farmers, as well as water managers and policymakers, in specific case study contexts in Tasmania and the Netherlands.

This thesis centres on five research questions:

1. What are the main challenges in assessing the regional feasibility of local water storage? (Chapter 2)
2. How can crossover points provide insights into farmers' preferences for various water sources? (Chapter 3)
3. Can participatory crossover analysis lead to a better understanding of personal reasoning behind investment decisions in extra water for irrigation? (Chapter 4)
4. Can a single participatory water valuation workshop foster social learning? (Chapter 5)
5. How can incorporating human-water interactions in regional water management contribute to achieving long term system level objectives? (Chapter 6)

Figure 1.1 illustrates the iterative and inductive relation between the different research questions.

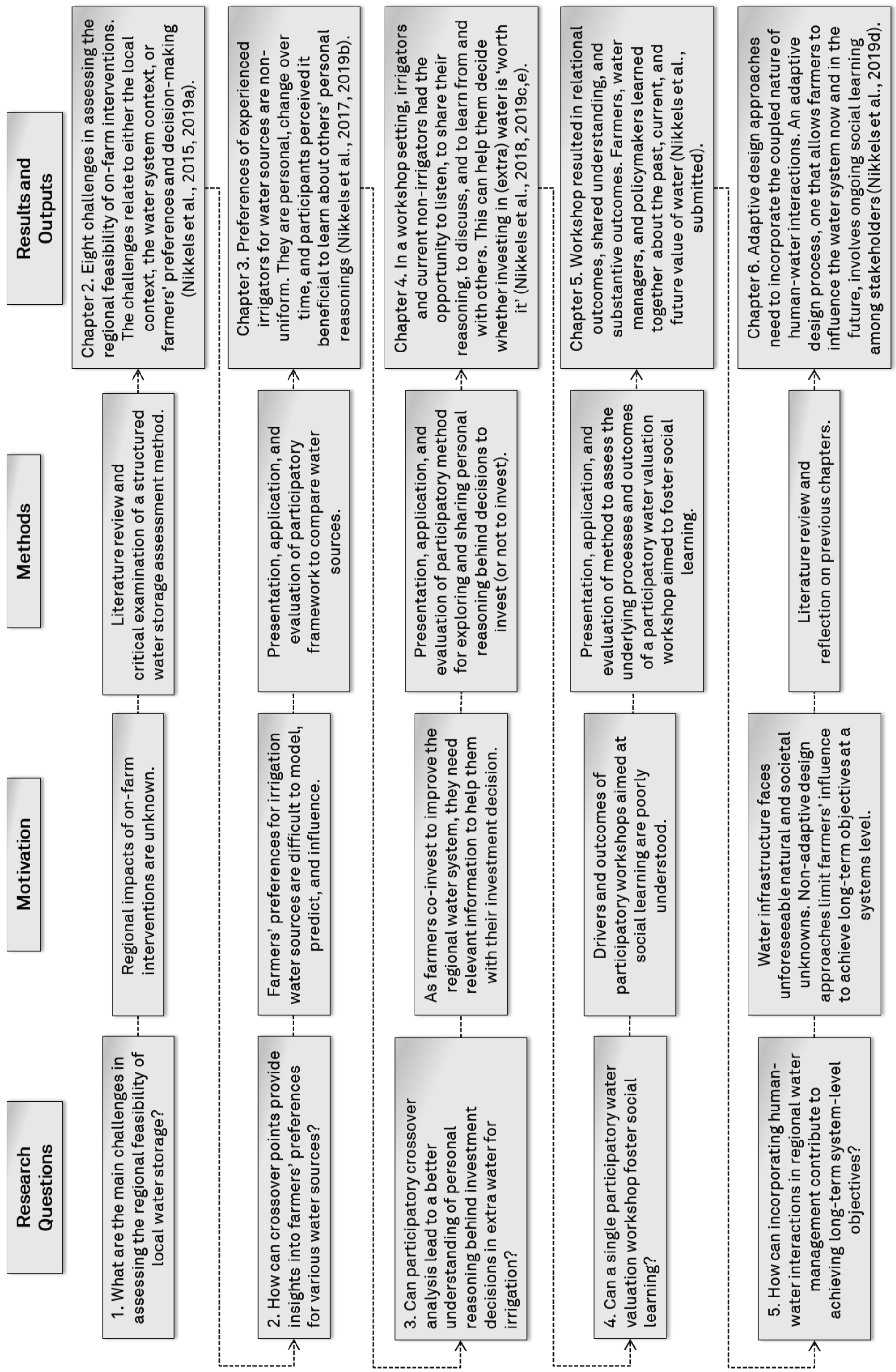

Figure 1.1. Overview of how the different research questions relate to each other and the methods used in this thesis

1.4. RESEARCH DESIGN AND THESIS OUTLINE

To answer the research questions, and thus to address the five knowledge gaps identified, a selection of research methods and approaches was used. The research process was iterative and inductive; that is, the outcomes yielded by addressing one research question were instrumental in motivating and influencing the work on the subsequent questions.

Chapter 2 focuses on the first research question. It reviews the literature on the potential of local storage and reflects on the application of a water storage assessment model and a cost-effectiveness analysis of seven on-farm interventions in North Holland, the Netherlands. The case study aptly illustrates why it is so difficult to assess the water storage potential of multiple local storages. This enables me to unravel some of the specific challenges involved. The literature review starts with van der Zaag and Gupta (2008), who called for research on the regional effects of local water storage interventions. Eight challenges are identified in assessing the regional feasibility of on-farm interventions. Key among these is the lack of understanding of farmers' preferences and decision-making. This is what motivated the second and third research questions, presented in chapters 3 and 4 (see Figure 1.1).

Chapter 3 builds on the crossover analysis literature, particularly Arshad et al. (2014) and Guillaume et al. (2016). It presents, applies, and evaluates a framework that extends the use of the concept of crossover points to a participatory setting. Crossover points represent conditions in which alternatives are equally preferable to a decision maker. The chapter presents a step-wise framework for crossover analysis, including the design, facilitation, and evaluation of a participatory workshop. The workshop design requires prior analysis of the context in which it is to take place, including semi-structured on-farm interviews with proposed participants. The evaluation process includes an exit survey on the process immediately following the workshop and telephone interviews later with questions on the perceived usefulness and learning. The main aim of this novel approach, termed "participatory crossover analysis", is to engage participants in a dialogue to explore their individual processes for arriving at personal preferences. The Coal River Valley in Tasmania provides the case study for this part of the research. Experienced irrigators here took part in a participatory crossover workshop exploring their personal considerations in decisions on investment in extra irrigation water. In a group setting, they discussed the influence of various characteristics of irrigation water (e.g. cost, quality, reliability, and manageability) on their preference for the different water sources available in their valley.

Chapter 4 builds on the previous chapter by applying the participatory crossover analysis framework in a water valuation setting. It presents a case study in which irrigators and non-irrigators in the valley adjacent to the Coal River Valley discussed their willingness to pay (WTP) for a right to one mega litre (1,000 m^3 = 1 ML) of irrigation water and the influence of quality, reliability, and manageability on their WTP. This case study explores the potential of a peer-to-peer workshop in which crossover points are used as WTP scenarios to stimulate a group of farmers to reveal and share a rich set of decision factors. The ultimate purpose was to better understand the personal considerations underlying decisions to invest (or not to invest) in extra water for irrigation. Such dialogue was found to be helpful in informing participants' future investment decisions and producing a better understanding of why others make different decisions, thus addressing research question 3.

Chapter 5 assesses the social learning potential of a workshop, making use of participatory crossover analysis as a tool to facilitate a deliberative dialogue between irrigators, scheme managers, and policymakers about the past, present, and future value of irrigation water. Again in a workshop setting, participants discussed implications of adaptive irrigation schemes in the South East Irrigation District, where the Coal River Valley is located, and explored the design and management of proposed schemes in Tasmania. Unlike the applications in the previous chapters, this workshop was not peer-to-peer focused, but instead took place in a heterogeneous setting with selected stakeholders representing different backgrounds, perspectives, and objectives (Figure 1.2). The novel approach for evaluating social learning in a group setting builds on the literature on social learning assessments, drawing particularly on the work of Scholz et al. (2014a), Kenter et al. (2016a) and de Vente et al. (2016). The evaluation process presented contains three evaluation points, spread over six months: an exit survey and workshop reflections immediately following the workshop, semi-structured telephone interviews approximately one month later, and one-to-one interviews six months after the workshop. The evaluation focus is on drivers (i.e., factors that positively influence social learning) and (emerging) outcomes of a single workshop that aims to foster social learning.

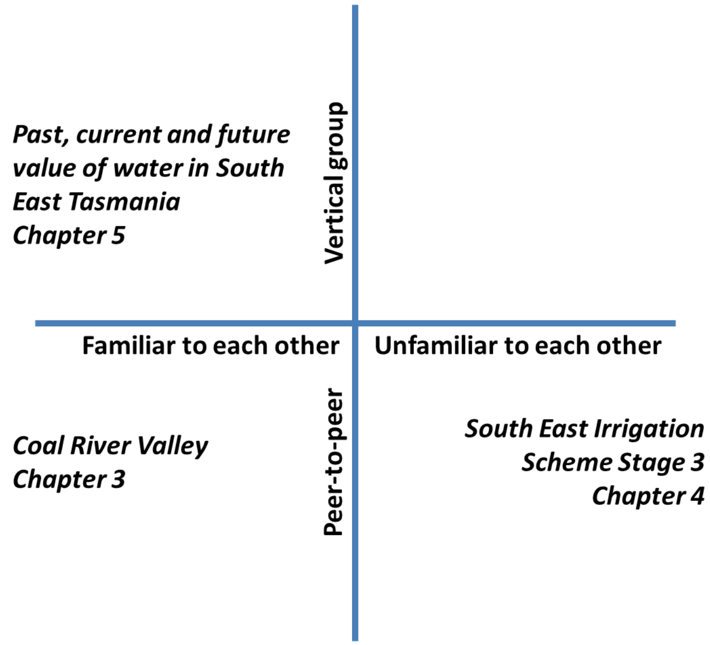

Figure 1.2. The settings in which this research applied participatory crossover analysis.

Chapter 6 adds a temporal component, addressing the non-stationary conditions in which both water systems and farmers function. Instead of examining farmers' influence on the regional water system, the chapter focuses on how a change in the water system might influence farmers, both current and future. Being adaptive to future unknowns allows farmers to participate and influence the water system. Based on a literature review in the domain of adaptive pathway planning (e.g. Haasnoot et al., 2013) and the literature on human-water dynamics (e.g. Srinivasan et al., 2017), the chapter provides valuable insights on adaptation in the context of irrigation systems. Findings from previous chapters and examples from the Murray Darling Basin in

Australia are used to highlight the need for planning and design approaches that embrace unknowns while recognizing the complexity of interactions between humans and water systems.

The final chapter of this thesis, Chapter 7, synthesizes answers to the research questions, introducing promising avenues for future work and positioning the insights that emerged during this PhD journey in a wider context.

For Dutch-speakers, chapters 2 through 6 offer a QR code. Scanning the code with a smartphone brings the reader to a podcast episode in which I informally discuss the chapter's content, including my main findings, with co-host Manne Havinga. The title of the podcast series is "PhD Proat met Melle en Manne". It can be found on Spotify and on the Aequator website.

1.5. RESEARCH CONTEXT

As noted above, the research questions were addressed drawing on case studies in the Netherlands and Tasmania (Figure 1.3). Though the Dutch and Tasmanian context have very different climatic regimes and socio-economic settings, in both cases, policymakers and water managers appeal to farmers to help improve the water system and contribute to long-term goals. As such, farmers' influence on the water system is high on the political and scientific agendas in both cases. In Tasmania, the long-term goal is to increase agricultural production value, whereas in the Netherlands it is to sustain the current water system.

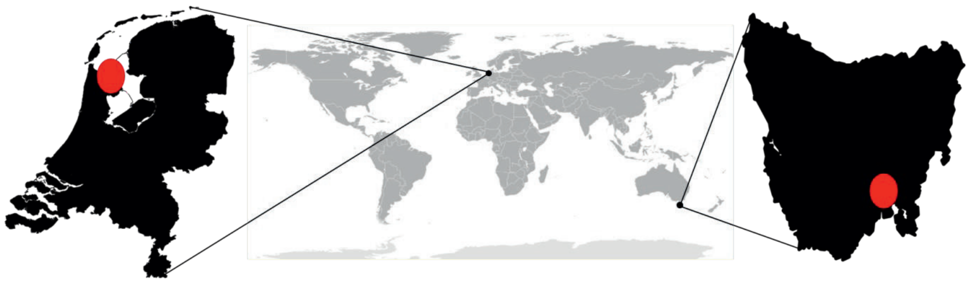

Figure 1.3. The Netherlands (left) and Tasmania (right), with the case study areas indicated in red. The Dutch case study site was in the province of North Holland. The Tasmanian case study site was in the south-east of the state.

The first case-study area is located in the province of North Holland, the Netherlands. Here the Hoogheemraadschap Hollands Noorderkwartier (HHNK) water board manages freshwater supply from Lake IJssel and Lake Marker. The Dutch case study consists of two, predominantly agricultural, regions: Wieringen and Wieringermeer. In this case-study area, intensive farming is challenged by salty seepage, water excess, and temporal irrigation water shortage.

In the Netherlands, local, regional and national stakeholders collaborate to improve the Dutch water system and make it more resilient. For example, work under the Dutch Delta Programme theme 'freshwater supply' explores strategies to sustain the current level of water availability for farmers (Ministry of Infrastructure and Water Management (I&M) & Ministry of Economic Affairs (EZ), 2014). The overarching objective is: *"To maintain a safe and attractive Netherlands, now and in the future, by providing adequate flood risk management and freshwater supply"* (Van Alphen, 2016). The programme has identified that farmers have a major role to play, as local interventions are seen as part of the strategy to reach the long term objective. However, this long term objective has been set without a clear understanding of the regional potential of local storage to reduce peak runoff and secure a reliable supply during periods of water shortage. In addition, many challenges remain related to co-investing in local on-farm interventions.

The second case-study area concerns an area in south-east Tasmania, Australia, where rainfall is supplemented by runoff water stored in on-farm facilities and water from communal irrigation schemes. Chapter 3 focusses specifically on the Coal River Valley. Farmers here gained experience with irrigation since construction of the Craigbourne Dam in 1986. Dam construction changed the valley dramatically. The direct and indirect benefits of irrigation water were initially hugely underestimated. Over the years, farmers developed their enterprises, intensifying production and increasing their demand for labour. Today, the Coal River Valley is held up as a beacon of the value of irrigation water and is seen as an example for other areas (Lejda et al., 2009).

The Tasmania case relates to an ambitious 2014 objective set by the state government: to achieve a tenfold increase in the farm gate value of agricultural produce by 2050 (AgriGrowth Tasmania, 2016, 2017). Water will be key to achieve such substantial growth (Leith et al., 2019). The government has therefore undertaken efforts to build new irrigation schemes to facilitate transformation from dryland cropping to more intensified forms of agriculture. In 2015, Stage 3 of the South East Irrigation Scheme (SE3) commenced operation, serving the Coal River Valley and adjacent valley with the most expensive water in the state (Tasmanian Irrigation, 2017). The approach used in the design of the new irrigation scheme included a feasibility phase in which farmers had to commit to buying water rights to cover at least 30% of the cost of scheme construction. The other 70% would be covered by Commonwealth and Tasmanian governments. During the pre-feasibility stage, information was provided to the farmers presenting the investment as a ‘once in a lifetime’ opportunity (Tasmanian Irrigation, 2012b), backed by facts and figures on costs and benefits (Tasmanian Irrigation, 2012c). Farmers in the adjacent valley, however, hesitated. Without the benefit of the almost 30 years of irrigation experience of their counterparts in the Coal Valley, many decided against investing in irrigation water. Their decision either to invest or not will influence the long-term distribution and availability of water in the region. The ‘once in a lifetime’ nature of the decision puts a cap on the maximum sustainable production in the region. The decisions made by these farmers were therefore instrumental in determining whether the long-term goal of the Tasmanian government could be achieved. My research centred on the area served by the SE3 scheme (Chapter 4) and the South East Irrigation District (Chapter 5), which includes both the Coal River and its adjacent valleys.

Beyond relevance to the examined case studies, it is my hope that the approaches presented in this research will prove more generally applicable. Many of the insights generated by this work could be helpful in overcoming challenges in assessing the impact of local interventions and farmers’ influence on regional water systems in other contexts as well.

2. CHALLENGES IN ASSESSING THE REGIONAL FEASIBILITY OF LOCAL WATER STORAGE

Scan me with your smartphone for a podcast on this chapter (in Dutch)

This chapter is adapted from Nikkels, M. J., van Oel, P. R., Meinke, H., & Hellegers, P. J. G. J. (2019). Challenges in assessing the regional feasibility of local water storage. Water International, 44(8), 854-870.

Regional effects of local water storage are largely unknown. This chapter identifies and discusses eight challenges in assessing the regional feasibility of local water storage. This overview is a first step to improving storage assessment tools and processes. The challenges are categorised into three clusters. The first cluster contains challenges related to comparing water storage interventions in their local context, including differences between techniques related to exploitability and the purpose of the water while stored. Interaction with other storages influences the feasibility of a certain option for a certain location. The second cluster deals with challenges of local storages in a water system context. Storage assessment approaches must shift their focus from storage 'potential', i.e. quantities of water that can be stored, to storage 'feasibility', i.e. the role that local interventions can play to improve the water system. Regional feasibility depends on the spatial and temporal scale of analysis and system dynamics including water supply- and demand dynamics of other water users. The third cluster goes beyond water and addresses challenges related to farmers' decision-making, as better understanding the influence of on-farm interventions requires approaches that go beyond focusing on local or regional hydrology. Investment decisions are hard to predict as they depend on the anticipated cost and benefits of water storage and use, which are difficult to quantify. To fully grasp the feasibility of local interventions, approaches need to be developed that provide insights into farmers' preferences for interventions.

2.1. INTRODUCTION

Temporal water shortage is a key constraint to food production in many countries (de Fraiture et al., 2013). This may worsen as climate change is expected to further amplify rainfall variability (e.g. Dore, 2005; Solomon et al., 2007). Water storage can mitigate water shortages due to rainfall variability. Appropriate water storage techniques can thus contribute to income and food security. Moreover, strengthening farmers' capacity to overcome drought contributes towards Sustainable Development Goal 2, zero hunger (United Nations, 2015) and 6, Clean water and sanitation (United Nations, 2018).

Ponds, farm dams, ditches, drainage systems and subsurface aquifers are some of the local water storage techniques that can help farmers overcome temporary water shortages by providing water for irrigation. Yet, the impacts of these local storage options at larger spatial scales are poorly understood, hampering assessments of how farmers (can) contribute to long-term system level objectives (ZON & DHZ, 2015). To grasp the potential of local storage as a strategy to increase water availability at the water system level, it is crucial to know what volume of water can be stored and the associated costs.

Thissen et al. (2015) defined a water system as a geographic area or region that depends on one or more water sources. Examples are a polder, a catchment or an irrigation scheme. The literature variously describes local storage techniques as 'scattered', 'small', 'fine', 'spatially distributed', 'decentralized', 'on-farm', 'on-field' and 'private'(e.g. Blanc, 2014; Fowler et al., 2015; Wisser et al., 2010). Local storage, furthermore, is taken to imply that the water stored is exploitable and regarded as private property (Feeny et al., 1990). FAO (2003, p. 4) defined exploitable water as 'water for use' or 'manageable water', to be applied for irrigation or to otherwise support crop growth and human activities.

Previously, van der Zaag and Gupta (2008) called for research on the regional effects of local water storage. They conducted an assessment focused on the choice between small and large surface reservoirs as an irrigation water supply strategy. Van der Zaag and Gupta (2008) compared the storage potential of a hypothetical large-scale dam of

$50*10^6$ cubic meter (m^3) to 2,000 on-farm tanks holding 500 m^3 each. According to these authors, the cumulative capacity of local storage systems is non-linear and difficult to predict, which makes choosing between the two strategies problematic. They concluded that for well-informed decision-making, we need a better ability to assess and quantify local storage potential and costs at the system level.

This knowledge gap is well known, but difficult to address. The first step to overcome it is to improve tools for assessing the cumulative impact of multiple local storage facilities in a system context. *Hence, the objective of this chapter is to identify and discuss challenges in assessing local water storage techniques at the regional, or system level.* We identify and discuss challenges based on a literature review and an examination of a structured water storage assessment method.

2.2. APPROACH

The research approach entails a literature review related to the article of van der Zaag and Gupta (2008) and a critical examination of a structured water storage assessment method applied to a Dutch case. The case serves to illustrate why it is so difficult to assess the potential of local storage techniques, enabling us to unravel some of the specific challenges involved.

LITERATURE REVIEW

Our literature review started with the study by van der Zaag and Gupta (2008). We sought out all 32 articles (July 2019) which cite their article to see by whom and how their call for research on the regional effects of local water storage was answered. Only 20 out of these 32 included the term ‘small’, ‘scale’ or ‘storage’ in their title, key words or abstract, of which 10 directly relate to the regional impacts of local storages (see Table 2.1). Papers that do not directly relate to the call for research on the regional effects of local water storage are summarized in Appendix I. All 10 directly related papers acknowledge some aspects of challenges in assessing local water storage techniques at the regional, or system level but are limited in their contribution towards improved storage assessment tools and processes.

Table 2.1. Conclusions and recommendations for further research of articles referring to van der Zaag and Gupta (2008).

Article	Conclusions and recommendations
van Oel et al. (2018)	van Oel et al. (2018) assess the role of large-scale reservoirs in the Jaguaribe basin, Brazil. They demonstrate that the spatial distribution of storages affects the duration and magnitude of hydrological droughts in both upstream and downstream. Although the impacts of on farm storages are not considered in their study, the authors suggest their assessment could be helpful in comparing the storage potential of large reservoirs with on farm storages.
Habets et al. (2018)	Habets et al. (2018) review modelling approaches to assess hydrologic impacts of small reservoirs. As their focus is on modelling river flow, they relate to water extraction for irrigation as an exogenous factor. These authors address the data needs relating to the water balance of small reservoirs, the losses, such as seepage and evaporation, and the connection to the stream, i.e. catching all or only a part of the river flow. They conclude that lack of data and model simplifications hamper regional impact assessments.
Van Meter et al. (2016)	Van Meter et al. (2016) assess the storage potential of rainwater harvesting tanks in India. These authors note the lack of empirical studies quantifying water fluxes, especially at the regional level. Local storage should not be evaluated in isolation, they observe, as tanks' position in the cascade strongly affects main water fluxes, usability and socio-hydrologic dynamics. (Socio-hydrologic dynamics was defined by Sivapalan et al. (2012) as the interactions between water and water users.)
Lasage and Verburg (2015)	Lasage and Verburg (2015) present a decision framework for selecting water-harvesting techniques. They observe that evaluation criteria, downstream consequences and the socio-economic impacts of water harvesting techniques are not well described in previous studies. They recommend agencies and donors to consider the impacts on livelihoods and the likely benefits of water harvesting techniques before advancing agricultural development and conclude that additional knowledge is needed on the downstream effects of cascading

	structures, to evaluate their sustainability and applicability.
Wutich et al. (2014)	Wutich et al. (2014) explore how socio-economic and environmental conditions shape peoples' perspectives, and preference for strategies to improve the water system. They find that preferences for hard path solutions – i.e. large scale, centralized infrastructures – versus soft path solutions – i.e. decentralized infrastructure and reforming of institutions – are influenced by people's development status and perception of water scarcity. They recommend future research to focus on ambiguities and people's perceptions in decision-making processes.
McCartney et al. (2013)	McCartney et al. (2013) develop a tool to assess four different storage options: large reservoirs, smaller ponds or tanks, groundwater and water stored as soil moisture. They stress that these storage options have distinct social and economic implications and differ in their reliability, resilience and vulnerability. As the authors acknowledge, their assessment of the effectiveness of ponds or tanks does not capture the cumulative effect of distributed, small-scale water storage in their case study applications in the Volta and Blue Nile basins in Ethiopia. They therefore call for further research on complementarities between different storage options and a focus on economic feasibility.
Lasage et al. (2013)	Lasage et al. (2013) evaluate the downstream effects of sand dams, under conditions of climate change in the Dawa catchment in Ethiopia. In their case study, additional sand dams lead to modest changes in downstream flows, but projected climate change and their maximum storage scenario case can extend the duration of low flow months by 50%. The authors indicate their assessment contains assumptions and uncertainties but stress that a management strategy to build small-scale structures can easily be adjusted when future unfolds and so allows for learning by doing.
Devineni et al. (2013)	Devineni et al. (2013) introduce spatially distributed indices for water stress. The indices reflect the deficit in a regional water balance, and recommend accounting for variability within and between years. They suggest that for large deficits, large surface storages are needed as small storages require a large fraction of arable land and recommend extending their approach by including interactions between surface- and groundwater.

Pandey et al. (2011)	Pandey et al. (2011) estimate seepage and evaporation losses of on farm storages in two locations in Texas (US) and West Bengal (India) concluding that shape, size and soil type of reservoirs were critical factors. They recommend embedding their model in a river scale model to assess downstream impacts. Seepage losses and evaporation reduce local water availability during the growing season but interaction with the water system was outside their scope. The authors also compare the cost and benefits of a distributed and a centralized system. They find that the cost/benefit ratio of many local storages exceeds a large reservoir but acknowledge that changing the assumed construction costs, size, material and water availability may alter their finding.
Thomas et al. (2011)	Thomas et al. (2011) review literature on temporal water storage options to sustain low flows in small catchments. The options include artificial groundwater recharge, surface water storage, wetlands and reuse of treated wastewater. They find that these options differ in their effectiveness, downstream influence, and controllability. They stress the need for further research, specifically synergies between flood protection and low flow augmentation, and incorporating climatic and anthropogenic changes.

Considering that the shared recommendation of the articles referring to van der Zaag and Gupta (2008) is that the regional effects of a set of local storages deserves further research, the following statement by van der Zaag and Gupta (2008, p. 11) is still relevant:

> *"We might have a fairly good idea of what the biophysical, economic, managerial and socio-political impacts are of a large dam with a capacity of, let's say two hundred million cubic meters; yet we do not know the precise impacts of one million small tanks with a storage capacity of two hundred cubic meters each."*

Obtaining a clear overview of the main challenges in assessing the regional-level impact of local water storage is an important first step towards improved storage assessment tools and processes that aim to inform farmers, water managers and policy makers.

THE FRESH WATER OPTIONS OPTIMIZER (FWOO) METHOD

The FWOO method, described by Hoogvliet et al. (2014), seeks to calculate how much fresh water can physically be stored in a particular region using a given set of storage techniques. Hoogvliet et al. (2014) selected seven storage techniques from the Dutch applied research programme ‘Knowledge for Climate’ (see www.knowledgeforclimate.nl/programme) (Table 2.2). With these techniques, water is stored underground and in ditches instead of using productive surface space.

Table 2.2. Local water storage techniques assessed using the Fresh Water Options Optimizer (FWOO) method, ordered by storage capacity. Source: adapted from Nikkels et al. (2015, Table 1).

Local storage technique	Description	ΔWater lens (m)	Storage capacity in m^3/ha
Aquifer Storage and Recovery (ASR) Coastal	Captures rainwater aboveground, using a vertical tube for it to slowly infiltrate salty groundwater. Freshwater is withdrawn from various depths to optimize recovery rates.	1.4	4,200
Freshmaker	Expands an existing shallow freshwater lens by infiltration of freshwater using a horizontal tube. An underlying tube withdraws salty groundwater.	0.66	2,000
Creek ridge infiltration	Enlarges a freshwater lens by raising the groundwater level by controlled drainage combined with infiltration of surface water.	0.5	1,500
Drains2Buffer	Deepens controlled drainage so that saline groundwater is discharged to surrounding ditches and the freshwater lens can grow with precipitation.	0.3	900
Controlled drainage	Allows the base drainage level to be adjusted throughout year, providing the possibility of raising the groundwater level to store water.	0.3	300
Water conservation with small weirs	Raises water levels in ditches, producing a larger buffer in surface water, but also raises the groundwater level in the surroundings.	0.2	200
Water conservation with ditch bottom elevation	By elevating a ditch bottom, groundwater levels in the surrounding area are raised while maintaining the same quantities of surface water.	0.15	150

The FWOO method asks two questions: 'where can a certain technique be applied' and 'what is the regional water storage potential of a set of local techniques'. This is complemented by a cost-effectiveness analysis (Nikkels et al., 2015). The method consists of six steps:

1. Analysis of water shortage
2. Mapping of physical suitability
3. Assessment of the impacts of measures on (saline) upward groundwater flows, groundwater and surface water
4. Assessment of the interaction between local techniques and the adjacent water system
5. Estimation of the maximum storage potential
6. Estimation of the water storage potential in the region

THE WATER MANAGEMENT CONTEXT AND CASE STUDY

The Netherlands sometimes experiences shortages of water quantity and/or quality (Ministry of Infrastructure & Environment (I&M) & Ministry of Economic Affairs (EZ), 2014). Availability of freshwater may be reduced further in the future, due to foreseen and unforeseen changes in supply and demand (Van Alphen, 2016). Climate simulations indicate that the agricultural sector could face losses of some €700 million every other year if the recurrence interval of dry years shortens from the current one in ten years to one in two years (Ministry of Infrastructure and Water Management (I&M) & Ministry of Economic Affairs (EZ), 2011).

Local, regional, and national water managers collaborate to improve the Dutch water system and make it more resilient. For example, work under the Dutch Delta Programme theme 'freshwater supply' explores strategies to sustain the current level of water availability for farmers (Ministry of Infrastructure and Water Management (I&M) & Ministry of Economic Affairs (EZ), 2014). Farmers co-operate with regional water managers and policy makers to improve the 'sponge capacity' of regional water systems (ZON & DHZ, 2015). The programme has identified local storage as part of the solution, but, so far, provided no clear insight into the potential of local storage to offer a secure supply during periods of temporary water shortage. Despite this lack of knowledge, national and regional water managers negotiate about more decentralized water distribution plans and strategies to reduce water demand from the central water supply system.

To better understand the implications of local water storage strategies, the Fresh Water Options Optimizer (FWOO) method has been developed and applied to a case study area in the province of North Holland. Here, the Hoogheemraadschap Hollands Noorderkwartier (HHNK) water board manages freshwater supply from Lake IJssel and Lake Marker. The regional Delta Programme has formulated a management strategy specifically for this area (Ministry of Infrastructure and Water Management (I&M) & Ministry of Economic Affairs (EZ), 2014). The case study consists of two distinct, predominantly agricultural regions: Wieringen and Wieringermeer (Figure 2.1). Wieringen is a former island, connected to the mainland since the 1924 reclamation of the Wieringermeer polder. Wieringen contains upward and downward seepage areas and has heterogeneously structured subsoil. The Wieringermeer polder is highly productive, with large areas devoted to agriculture, horticulture and greenhouses. The topsoil here is clayey, and the subsoil consists of sand and clay layers.

Figure 2.1. Case study area in dark grey

The case study area has a long history of water-related stress. In summer, the salt content in ditches increases due to upward seepage of brackish groundwater. This water quality problem becomes more severe when water intake from Lake IJssel is no longer possible or allowed, for example, during drought. The dry year of 2003 caused significant drought-related yield losses (van Bakel et al., 2008). While in theory, water could be supplied to the region by Lake IJssel and Lake Marker (Ministry of Infrastructure and Water Management (I&M) & Ministry of Economic Affairs (EZ), 2014), water of adequate quantity and quality is not always available at the right place and at the right time.

THE FWOO OUTCOMES IN THE CASE STUDY AREA

The FWOO assessment concluded that 16 million m^3 could be stored in Wieringen and Wieringermeer using the seven local water storage techniques (Nikkels et al., 2015). To put this into perspective, 16 million m^3 is equivalent to 72 mm per square metre, or

32% of the summer rainfall deficit in a typical dry year (i.e., one with a recurrence interval of every ten years and a precipitation deficit of 220 mm) (Ministry of Infrastructure and Water Management (I&M) & Ministry of Economic Affairs (EZ), 2011). This is an appreciable quantity, as it is more than the annual volume supplied from Lake IJssel, which is 11 million m^3. The cost per cubic metre stored was found to vary, from €0.07 for 'Aquifer Storage and Recovery Coastal' (ASR Coastal) to €1.04 for 'water conservation with small weirs' (Nikkels et al., 2015). Discount rates, time horizons and assumed life spans influenced the cost-effectiveness rankings.

2.3. CHALLENGES IN ASSESSING THE REGIONAL FEASIBILITY OF LOCAL WATER STORAGE

Based on our literature review and critical reflection on the FWOO case study, we identified eight challenges, grouped into three categories (Table 2.3). The categories are local context, water system context and farmer investment decisions.

Table 2.3. Eight challenges in assessing the regional feasibility of local water storage techniques based on literature and FWOO application.

Challenges	**Based on literature in Table 2.1**	**Based on FWOO application**
Local context		
1. Exploitable volumes differ due to differences in manageability and rechargeability.	(McCartney et al., 2013; Van Meter et al., 2016)	✓
2. Stored water serves additional purposes, such as preventing saltwater intrusion into the plant root zone.		✓
3. Storages impact their direct surroundings, influencing the local feasibility of other techniques.	(McCartney et al., 2013; Thomas et al., 2011)	✓
Water system context		
4. The spatial and temporal scales of analysis influence assessment findings regarding the overall feasibility of local storage.	(Devineni et al., 2013; Habets et al., 2018; Lasage et al., 2013; Lasage & Verburg, 2015; Van Meter et al., 2016; van Oel et al., 2018)	✓
5. Uncertainty about the local availability of water to fill local storage installations reduces reliability.	(McCartney et al., 2013)	✓
6. The actual contribution of local storage to regional objectives is influenced by incorporating alternative sources such as return flows, reuse and regional storage.		✓
Farmer investment decisions		
7. Costs and benefits of local storage are hard to quantify, especially when benefits pertain to various spatial and temporal scales.	(Lasage & Verburg, 2015; Pandey et al., 2011)	✓
8. Farmer investment decisions are difficult to predict and may depart from the economically optimal option.	(Lasage et al., 2013; Wutich et al., 2014)	

LOCAL STORAGE TECHNIQUES AND THE LOCAL CONTEXT

The first challenge identified in the local context is the fact that exploitable volumes may differ due to differences in manageability and rechargeability. The FWOO method compares storage techniques based on their storage potential at the beginning of the growing season, assigning the same monetary value to each cubic metre of water stored. As such, the method bypasses the distinct characteristics of the different storage options, and manageability remains unaccounted for. This introduces uncertainty to the method's comparisons, see Lasage and Verburg (2015).

For instance, there is a difference between 'water-in-the-hand' techniques, such as Freshmaker and ASR Coastal, and 'water-in-the-land' techniques (the other five techniques considered, see Table 2.1). Water-in-the-hand techniques store water in waterbodies, from which farmers can extract it when needed. Water-in-the-land techniques store water in the ground at or near the root zone where it is readily available to plants. The manageability of water stored 'in-the-hand' is therefore greater. Moreover, water-in-the-land is already in use while farmers can still extract from other sources, such as nearby surface waters. As a result, it may not be available when it is really needed. The actual usefulness of 'in-the-land' techniques is therefore different from the storage potential.

Furthermore, all local storage techniques included in the FWOO assessment may be filled or recharged multiple times during a summer period. This, too, introduces uncertainty to the determination and comparison of their cumulative storage capacities. In a rain event – or in the case of Wieringen and Wieringermeer, when withdrawals can again be made from Lake IJssel – local storage can be refilled. The recharging capacity differs across techniques and depends in part on seasonal conditions and location, which complicates comparisons even more (Lasage et al., 2013). These complicating factors suggest that we need to shift our focus from storage potential to storage feasibility, as improving exploitable water availability involves more than just increasing quantities at the beginning of the growing season.

A second challenge in assessments of local storage relates to the multiple purposes for which water can be stored (Turner et al., 2004). For instance, stored water can prevent saltwater intrusion in the plant root zone. A stored volume of freshwater can have a dual purpose if a relatively small additional amount of freshwater (e.g., provided by the Drains2Buffer or Freshmaker technique) can prevent saline seepage into the root zone (Zuurbier et al., 2016). Such buffering or shielding capacity confers an added value to some stored water units, compared to water that can be used for irrigation purposes only. However, the FWOO method cannot account for this multipurpose characteristic.

Third, the use of certain water storage techniques can have considerable physical or regulatory flow-on consequences, extending to adjacent areas. For instance, water stored using an ASR Coastal system requires implementation of a 'no go' zone for other wells (Ministry of Infrastructure and Water Management (I&M) & Ministry of Economic Affairs (EZ), 2015). Techniques that raise water levels in ditches (e.g., water conservation with small weirs) can result in additional water stored in the drainage systems of adjacent fields. While such flow-on impacts are identified in steps 3 and 4 of the FWOO method, their interdependencies are not quantified. Nonetheless, interdependencies can be important, as the best option for water storage might depend on the storage activities of neighbours. It might even be possible to join efforts and cooperate with neighbours and other stakeholders or to implement two techniques at the same location. Therefore, the specificity of the storage location and adjacent storage activities should also be taken into account in local storage technique assessments.

LOCAL STORAGE TECHNIQUES AND THE WATER SYSTEM CONTEXT

The feasibility of local water storage techniques and their impacts at the water system level strongly depend on the broader characteristics of the water system. Hence, the feasibility of local storage options is context specific. This notion leads to our next three challenges.

Thus, our fourth challenge is that any intervention in a water system affects temporal and spatial water availability elsewhere. While local storage might increase the exploitability of water at one location, it could also reduce the exploitability of water downstream, see e.g. (van Oel et al., 2018). This applies to any storage technique, to a change in the water table, and to irrigation practices (Masih et al., 2011; van Halsema & Vincent, 2012). Whether a reallocation of water is desirable from a regional perspective depends on the regional water management objectives. The FWOO method focuses on storing water for private use, without fully quantifying system-level effects. This means that regional effects go largely unevaluated, given the impacts of local storage on water availability at different locations and times, through effects on peak flows, base flows and overall water resource distribution (e.g. Di Baldassarre et al., 2018; Krol et al., 2011; WCD, 2000). These scale interactions were acknowledged by Habets et al. (2018) Lasage and Verburg (2015) and Van Meter et al. (2016). Nonetheless, they remain poorly understood, hampering local storage technique assessments.

The Dutch national water system, for instance, supplies multiple water management regions. In the case study area, reduced demand for water from the central source (Lake IJssel and Lake Marker), could potentially benefit other areas that get their water from the same source. A better understanding of these interdependencies at the system level could yield better infrastructure investment decisions. This could ultimately improve the efficiency and effectiveness of regional water systems by strategically positioning local water storages.

Fifth, there is often uncertainty regarding whether enough water will be available locally to fill small-scale storage structures. This complicates our assessments of the feasibility of using a local storage strategy to increase water availability. The FWOO method assumes that water will be available in the wet winter months to fill storages with high quality freshwater. Indeed, Lake IJssel receives much more water than it can store, and excess is discharged into the Wadden Sea. Although the assumption of abundant winter inflows might be valid at the case study location, it may not hold true elsewhere in the Netherlands and around the world.

Sixth, varying preferences and needs among competing water users – particularly, agriculture, nature, industry and urban areas – might offer opportunities for water storage and reuse. Yet, return flows are currently unaccounted for in the FWOO method. Water is thought of in linear flows and singular (high) quality provision.

However, variety in the temporal and qualitative demands of different water users might yield storage and reuse opportunities. In the Netherlands, local storage tends to be used for supplementary water; it serves as an alternative source when other sources (usually surface water) become scarce or fall dry. Therefore, at least in the Netherlands, we should not limit ourselves to comparisons between central large-scale storage and decentralised local storage techniques, as in van der Zaag and Gupta (2008). Instead, we should try to understand where, how and what local storage techniques could be applied to supplement water availability from central large-scale sources (Figure 2.2).

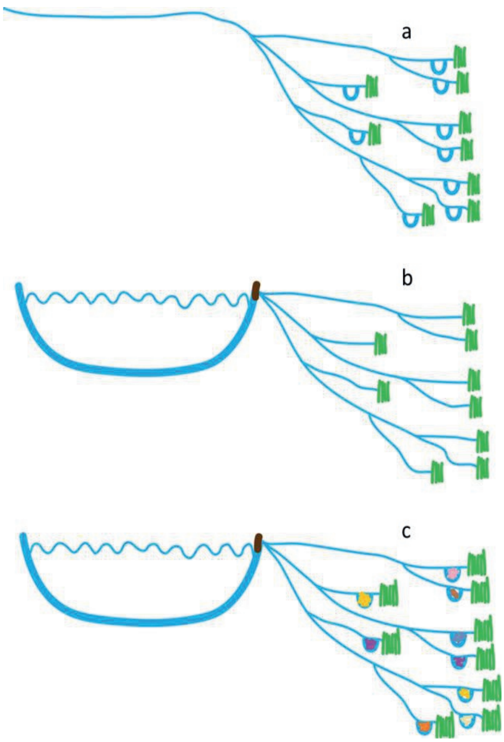

Figure 2.2. We need to shift from comparing decentral (2a) versus central storage (2b) to assessing where and how a set of local storage techniques can support water supply from a large-scale storage system (2c)

According to Blanc (2014), when large and small-scale storage complement each other, the combination of the two can improve water availability for irrigation. A better system-level understanding allows investments in various forms of water storage at strategic locations, resulting in improved robustness of the regional water system.

In the case study area, local storage techniques could bridge relatively short drought peaks, delivering freshwater to the capillaries of the system. A regional freshwater shortage analysis, as in step 1 of the FWOO method, should therefore start with an investigation of how local storage might 'improve' rather than 'increase' water availability at the appropriate level. The focus here would thus no longer be on storage potential, but on the feasibility of using a local storage strategy to augment water supply in a specific location and context.

LOCAL STORAGE TECHNIQUES AND FARMER INVESTMENT DECISIONS

The costs of investments in water storage depend on many factors. The cost-effectiveness calculation for the FWOO storage techniques presented in Table 2.1 represents an attempt to compare and rank options based on the cost of storing one cubic metre of water (Nikkels et al., 2015). The aim was to know what volume of water can be stored and the associated costs, to explore to the optimal set of storages. However, there are large uncertainties in storage capacity, life spans and costs of various components. These will influence the ranking of the techniques. For informed decision-making, a much more detailed understanding of the local context, the factors that influence comparison (ranking) of storage options and their (financial) feasibility is needed. This leads to our final two feasibility assessment challenges that go beyond hydrology, categorized under the heading of farmer investment decisions.

Our seventh challenge is the fact that the costs and benefits of local storage, and water in general, are diverse and hard to quantify (Pandey et al., 2011; Savenije & Van der Zaag, 2002; WOCAT, 2007). Water can have cultural, environmental, religious and social benefits, of which the perception is personal (Davidson et al., 2009; Garrick et al., 2017). In addition, costs and benefits of extra water to irrigate crops may differ per year and season, due to variations in commodity prices, usage, rainfall and quality, to name just a few (Turner et al., 2004). Determination of benefits, both monetary and non-monetary, and trying to compare and rank options becomes even more challenging if stored water serves multiple purposes. Beyond producing local benefits, the water system may receive benefits from local private investments in local storage, which may give governments an opportunity to reduce or postpone their own investments in infrastructure, such as a centralised large-scale reservoir or flood mitigation measures. Benefits they yield at the system level are hard to quantify and can be far removed in both location and time. This makes fair allocation of the investment costs another challenge, especially when the benefits of local storage are not enjoyed at the location where the implementation costs are incurred.

Our final, eighth challenge relates to farmer decisions to invest in local water storage which is outside the scope of the FWOO. From a policy perspective, it is important to understand how farmers conceptualize the situation and potential solutions (Wutich et al., 2014) and under which conditions actors make investment decisions. Economics models often rely on a rational economic actor, who seeks to maximize a goal function under conditions of perfect information and in the absence of biases or unequal power relations. Empirical evidence shows, however, that real economic choices often deviate from this model, especially if made under uncertainty (van Duinen et al., 2015; Veraart et al., 2017). Choices are made based on value-for-money and functional factors, but also for emotional and social reasons (Vanclay, 2004). Van Duinen et al. (2016) found farmers' uncertainty thresholds, aspiration levels, social network characteristics, heuristics and expectations all to be important factors of drought adaptation behaviour. Preferences among techniques might therefore be personal, in which case a structured assessment method, like FWOO, might best be used as a discussion support tool rather than for decision-making (Guillaume et al., 2016; Nelson et al., 2002). As farmers might have personal preferences and make different investment decisions than their peers, the focus of the discussion should then no longer be on 'what is right' and 'what can be counted', but instead focus on 'what counts', assumptions and personal reasoning, see Chapter 3&4.

2.4. DISCUSSION AND POLICY IMPLICATIONS

The feasibility of local water storage techniques and their impacts at the water-system level strongly depend on the characteristics of the regional water system. In our case, some of the characteristics are not representative for other cases in the Netherlands, nor the world. The ability to recharge local storages during the season, for example, differs across techniques and locations within the case study area, but is not possible in many other cases. In addition, serving multiple purposes, e.g. preventing saltwater intrusion in the plant root zone, is also context-dependent. Salt water intrusion is increasingly a problem in Wieringen and Wieringermeer (Oude Essink, 2001) – as in many other deltas (see e.g. de Louw et al., 2010). However, the multiple purpose function might be more related to the water system in other contexts. For example, in more mountainous regions, the ability to influence peak flows and to strategically release water to improve flow might be multiple purposes that should be taken into account when comparing options, as in Thomas et al. (2011). Other purposes that go beyond storage capacity, such as the ability to provide ecosystem services might also be factors worth considering when comparing storage techniques, see e.g. Mul and Gao (2016).

From a water-systems perspective, the roles of storages are relevant to consider. Unknowns in climate trajectories and in the demand for water might call for different roles of local storages in the future. In addition, variability of water availability between and within years complicates the assessments of local storages (Devineni et al., 2013; Habets et al., 2018). These variations and unknowns add to the complexity of assessing their long-term feasibility (see e.g. Lasage et al., 2013; McCartney et al., 2013). In the Netherlands, local storage is currently a supplementary water source; it serves as an alternative when other sources run dry. In most parts in the Netherlands (under normal conditions), this would be surface water, but during droughts, farmers might use piped municipal water for irrigation, or arrange for trucks to haul in water, though this incurs additional production costs. Elsewhere in the world, local storage may constitute the principal – or even the only – means of increasing the amount of water available in the growing season (e.g. Hughes & Mantel, 2010; van Oel et al., 2011).

In other contexts, interaction between surface and groundwater (see e.g. Devineni et al. (2013)) and the co-dependencies between built and natural water storages might influence the feasibility of newly built storages . Mul et al. (2015) discuss how natural storages can have positive effects on water quality, which then relates to the maintenance requirements of built storages. Saruchera and Lautze (2019) found that in Africa, sedimentation and poor maintenance are key factors determining performance during the lifespan of storages. They argue that for improving the performance of storages, strong institutions are needed and raise the issue that NGO's and governments may lack incentives to finance well-structured storages that have a long lifespan. In other contexts, the regional feasibility of local water storage might be more strongly linked to institutional and financing challenges.

The challenges related to investment decisions are not water-sector specific. They also pertain to the energy sector, to name one example. Optimal deployment of centralized and decentralized energy resources at the system level is a key challenge in multi-energy systems (MES) and features prominently in concepts such as the 'smart grid' (Mancarella, 2014). Mancarella (2014) pointed to the general lack of understanding of the economic feasibility of future 'smart' MES systems, under current and future uncertainties. A comparison of the consumer energy cost for a mix of centralized and decentralized heat and power techniques revealed that optimal solutions may be found in combinations of both (Aki et al., 2006).

Developing policies that align private and public initiatives and support innovation often requires changing existing institutional arrangements and their governance (Godfrey-Wood, 2016). New policy options might emerge from social learning approaches in which actors learn from and with others, defined as 'learning together to manage together' by Ridder et al. (2005). A policy implication is that such social learning processes could provide valuable information and insights into the factors that influence personal preferences and could enrich the knowledge of potential investors so they can make better-informed investment decisions. This is beneficial for the cooperation between farmers and water managers and would contribute to reaching both on-farm and water system objectives.

These complicating factors strengthen our argument to shift from focussing on storage potential to storage feasibility. Feasibility determination is very context specific; the roles that local storages (can) play to improve regional water availability varies depending on the unique characteristics of the water system, but also on the objectives of (long term) water management, institutions and policy plans. See Box 2.1 for an example of the regional feasibility of a local desalinator.

We hope that the identified and discussed challenges raise awareness and function as warnings for anyone undertaking an analysis of local storage techniques. As such, this article concurs with van der Zaag and Gupta (2008), who called for research into the cumulative effects of local water storage techniques. This first step provides guidance for further research in assessing the regional feasibility of local water storage in various settings and from different (inter-) disciplinary perspectives.

Box 2.1. Fource: the farmers' fresh water source, experiences with a local desalinator

In the first two and a half years of this PhD, I was part of a start-up, called Fource. In partnership with Aequator Groen & Ruimte B.V., Wageningen Environmental Research (Alterra), VGB Watertechniek B.V. and Voltea B.V., Lodewijk Stuyt and I worked on a technological innovation to turn brackish (unsuitable) water into suitable water for irrigated agriculture. We used "Membrane Capacitive De-Ionization" (CapDI), developed by Voltea to extract salt from water, using a potential difference across electrodes. The idea was that we would tailor-make irrigation water, adjustable to farmers' preferences; see e.g. van de Craats et al. 2016.

After almost three years, we came to the conclusion that we could not yet meet the requirements to develop a market-oriented desalinization system, mostly due to the lack of sturdiness, high costs, and the residual flow of high saline water. This residual flow, called brine, influences the water system. When only one desalinization system is in use, the effects of discharges in the surface water are small. However, when more desalinization systems are in use, brine negatively affects surface water quality, which does not align with Dutch regulation by water boards. At first, this diminishes the regional feasibility of local desalinization techniques. Yet, when the locations of the desalinisation systems are strategically placed, to make sure that the system provides the freshwater supply of the most salt sensitive crops, it may be acceptable to have a higher salinity level in surface waters. Another option could be the implementation of separate drainage ditches for salty and fresh water. In the Dutch case study area of this chapter, local desalinization systems would reduce the necessity of continuously pumping-in fresh water, significantly reducing costs for the water board and providing options to optimize the usage of water, especially during periods of water shortage. Scaling up of local desalinization systems is subject to nonlinearities and may contain tipping points; an interesting avenue to further explore the regional feasibility of local interventions.

2.5. CONCLUDING REMARKS

The objective of this chapter was to identify and discuss challenges in assessing the regional feasibility of local water storage techniques. We presented eight such challenges (Table 2.2). We found that the cumulative effect of multiple local storage techniques in a water system is not a simple aggregation of individual outcomes. Indeed, the aggregate potential of local water storage, measured by the quantity of water that could be stored and the corresponding costs, might differ from the amount of storage that such systems can feasibly be expected to provide on a regional scale. Thus, we argued that the focus needs to shift from storage 'potential' to 'feasibility'.

Local water storage techniques may have the potential to improve regional water availability, but our understanding of the feasibility of using combinations of different local techniques remains vague, due to the eight challenges identified. These challenges were grouped into three categories: local context, water system context and farmer investment decisions. Firstly, the local context needs to be analysed and understood before it can be included in any meaningful analysis. Feasibility depends on the exploitability, purpose and interactions of the various water storage alternatives. Secondly, the spatial and temporal scales of analysis have considerable influence on feasibility. Finally, investments in local storage will hinge on the benefits of the stored water and on the investment preferences of farmers, who are influenced by difficult-to-quantify factors, such as risk aversion and personal values.

We conclude that in order to make the best possible policy and investment decisions for local water storage, concerted effort is needed regarding each of the identified challenges, to improve storage assessment tools and processes.

3. PARTICIPATORY CROSSOVER ANALYSIS TO SUPPORT DISCUSSIONS ABOUT INVESTMENTS IN IRRIGATION WATER SOURCES

This chapter is published as Nikkels, M. J., Guillaume, J. H. A., Leith, P., Mendham, N. J., van Oel, P. R., Hellegers, P. J. G. J., & Meinke, H. (2019). Participatory Crossover Analysis to Support Discussions about Investments in Irrigation Water Sources. *Water,* 11(7), 1318.

Regional water managers increasingly count on investments by local water users such as farmers. Farmers' investment decisions are difficult to predict. Local circumstances and individual situations vary and investment decisions are made under uncertainty. Water users may therefore perceive the costs and benefits very differently, leading to non-uniform investment decisions. This chapter investigates whether this variation can be explored in a workshop setting, using crossover points. A crossover point represents conditions in which a decision maker assigns equal preference to competing alternatives. This chapter presents, applies and evaluates a framework extending the use of the concept of crossover points to a participatory process in a group setting. We applied the framework in a case study in the Coal River Valley of Tasmania, Australia. Here farmers can choose from multiple water sources. In this case, the focus on crossover points encouraged participants to engage in candid discussions exploring the personal lines of reasoning underlying their preferences for various water sources. Participants learned from others' inputs, and group discussions elicited information and insights considered valuable for both the participants and for outsiders. We conclude that the approach has high potential to facilitate learning in groups and to support planning.

3.1. INTRODUCTION

Uncertainty and complexity, related to changing and variable climatic and economic conditions, create an imperative for strategic and adaptive decision-making on strategies to secure irrigation water availability (Allan & Curtis, 2005; Haasnoot et al., 2013; Pahl-Wostl, 2009). To enhance adaptive capacity, long-term regional water management plans depend increasingly on investments by local water users (Turral et al., 2010). When on-farm investments can substantially influence regional water availability, regional water management organisations need a good understanding of how and when decisions are made to invest in water. If multiple irrigation water sources are available, farmers may display a clear personal preference when comparing alternatives. A personal preference is determined by the sum of an individual's reasoning regarding options. Reasoning and preferences on irrigation options may vary for many reasons: heterogeneity of local circumstances and situations; real and perceived uncertainties; perceptions of the value of water for irrigation; and tacit knowledge. Generically speaking, personal preferences may differ depending on (1) the set of factors considered, (2) how the factors are understood and integrated into reasoning and (3) the value that individuals attach to each factor.

Whether implicit or explicit, farmers base their investment decisions on individualised reasoning (Öhlmér et al., 1998). Assuming that a group of farmers will uniformly invest if a model indicates a venture to be "worthwhile" might therefore be inaccurate. This suggests the need to better understand the personal reasoning process that underlies decisions on water needs and preferences among sources. Such insight could be particularly valuable to other water users, alongside irrigation scheme designers and water managers.

Crossover points can be used to compare personal preferences and analyse the reasoning underlying them. A crossover point indicates the conditions under which an individual equally favours two alternatives. Analysis of crossover points, expressed as points of indifference, focuses on two key questions: (1) Under what conditions does one alternative out-favour another? (2) What drives personal preference? Crossover analysis is a broadly applicable concept rather than a specific evaluation method (Frey & Patil, 2002). It has been applied for a wide range of purposes:

- to assess the economic feasibility of crop production under uncertainty (Dillon, 1993)
- to determine breakeven points in cost and utilization of managed medical care ((Boles & Fleming, 1996)
- to study points of indifference in pigeons between a small portion of food now versus a delayed but bigger portion (Mazur, 2000)
- to determine at what distance from an existing utility line a stand-alone alternative energy system becomes cost-effective compared to a conventional transmission line (Ekren et al., 2009)
- to assess uncertainties in the costs and benefits associated with managed aquifer storage and recovery for improving irrigation water use efficiency at farm level (Arshad et al., 2014)

The crossover point concept has also been used to explore the sensitivity of modelled outcomes to assumed values for relevant factors in Multi-Criteria Analysis (MCA) (Guillaume et al., 2016; Hyde & Maier, 2006; Ravalico et al., 2010). Guillaume et al. (2016) built on the idea of crossover points to help analysts intuit how crossover points change when adjusting input values in a MCA, specifically, in regard to irrigation water storage options and the footprints of a vegetarian versus non-vegetarian diet. These authors developed an interactive web interface that visualises the consequences of assumptions on rankings of alternatives. This tool helps analysts to explore crossover points in a learning context.

Discussing crossover points has considerable potential in supporting learning among actors. However, this can best be achieved when the analytical power of crossover analysis is put in the hands of stakeholders. Voinov et al. (2016) encouraged the addition of stakeholder experience and expertise in modelling processes. Yet, many existing decision support applications assume an objective “optimal” outcome based on a decision rule and clearly defined factors that can be captured in a model, such as cost minimisation, in which the cheapest alternative emerges as “best” (e.g. Arshad et al., 2014; Ekren et al., 2009). Avoiding the assumption of a single “best” option broadens the discussion, as in many cases “what is best” is far from objective but is, at least in part, a personal preference subject to change over time (Hermans et al., 2006b). It may even be political (Hellegers & Perry, 2006).

This chapter contributes to the crossover literature by presenting a framework that extends the use of the concept of crossover points to a participatory setting. The aim is to elicit discussions among water user on investments in irrigation water sources. This is somewhat analogous to what Nelson et al. (2002) termed ‘discussion support’ rather than ‘decision support’. The discussion of crossover points in groups is open-ended and subjective, and no single “optimal solution” is pursued. Indeed, personal crossover point indications need not be certain or “right”, and no agreement on probabilities is required. This shifts the crossover exercise away from problem solving towards a learning mode, with future uncertainties, personal reasoning and assumptions at the forefront. The main aim of this new approach, termed participatory crossover analysis, is to engage participants in a dialogue that explores the personal reasoning process by which preferences are defined. During the discussion, participants receive input from others and contribute their own information and insights regarding qualitative and quantitative aspects of alternative irrigation water sources for the benefit of both the participants and outsiders. Pahl-Wostl (2017) considered such informal sharing and integration of knowledge as key for improving water management and governance.

To provide a first, low-stakes test of the framework, we applied it in the Coal River Valley of Tasmania, Australia, where farmers have access to multiple water sources. We begin by presenting the method of participatory crossover analysis and examine its use in the case study. We then explore the implications of the participatory crossover exercise and evaluate the framework.

3.2. MATERIALS AND METHODS

We developed a step-wise framework for participatory crossover analysis that can serve as a checklist for organising a workshop. The framework is formulated in general terms, to allow its application in various settings and situations. We tested the framework, with both a practical and a theoretical aim. The practical aim was to facilitate discussions among experienced farmers about irrigation water sources in the Coal River Valley of Tasmania. Specifically, participants discussed how and why their crossover points differed and any changes in their reasoning over time. The theoretical aim was to test whether the framework was applicable (yes or no) and worthwhile (measured by whether participants perceived it as useful). To evaluate the theoretical component, a two-step evaluation process was developed.

FRAMEWORK FOR PARTICIPATORY CROSSOVER ANALYSIS

Figure 3.1 presents the five-step participatory crossover analysis framework. Step 1 concerns the aim of the exercise. Why will a participatory crossover analysis workshop be useful? What discussion and learning is expected? Table 3.1 lists the aims that participatory crossover analysis can satisfy. Proceed to step 2 only if the aims are clear and suitable.

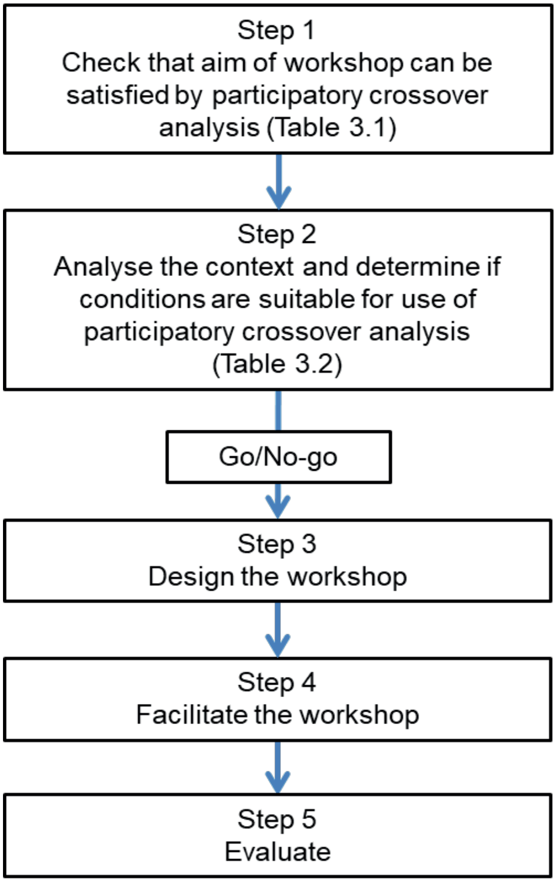

Fig. 3.1. Stepwise framework for participatory crossover analysis

Step 2 is to analyse the situation and context of the foreseen participatory crossover analysis workshop. This may involve interviews with proposed participants and should lead to a preliminary identification of alternatives, existing personal preferences and the factors that influence personal preferences. Table 3.2 lists conditions required for participatory crossover analysis to succeed. Proceed to step 3 only if all the conditions in Table 3.2 are satisfied. This may require taking actions that establish suitable conditions, as was done in Chapter 4.

Table 3.1. Participatory crossover analysis is considered suitable to achieve one or more of the following aims

Elicit personal reasoning	Participants will be encouraged to share the factors they consider in decision-making, what those factors mean to them, how they integrate them and the value of each
Improve understanding of where differences in preferences come from	Participants will be given opportunities to reflect on their own personal reasoning and compare it with others, helping them to learn why preferences differ
Explore robustness of personal preferences	Participants will learn about the conditions under which preferences change, gaining a sense of their robustness. This encourages them to think about the likelihood that such conditions will occur
Provide inputs for regional planning affected by individual decision-making	Sharing decision rules and preferences and providing background information for planning will help participants make or better understand investment decisions

Step 3 is to design the workshop. Design affects both the workshop process and the content of the discussions (Scholz et al., 2014a; Stringer et al., 2006). Think about who will participate. What is their role? Where will the workshop take place? How long should the workshop last? What visual aids might benefit the discussions? The answers to these questions will help determine how the concept of a crossover point should be introduced and what crossover points will be discussed.

Table 3.2. Participatory crossover analysis is considered suitable only if ALL of the following conditions are met

Preferences are subjective	In participatory crossover analysis, there is no objective optimum. Uncertainty is recognized in assessment of alternatives, and reasoning is understood to be at least partly individual. In other words, what is “best” for me might not be “best” for you. To decide what is “best”, we each have our own personal decision rules based on explicit and tacit knowledge. If this condition is not met, a more structured approach could be used (see, e.g., (Guillaume et al., 2016)).
At least two discrete alternatives to compare	Participatory crossover analysis requires at least two discrete alternatives to compare, based on one or more factors, which may be uncertain or incomplete. Alternatives may be, for example, whether or not to invest or to adopt an innovation. The crossover concept does not easily translate to continuous decisions, such as how much to invest.
A dialogue situation	Participatory crossover analysis requires opportunity for a dialogue, for example, a group discussion, in which participants experienced with the alternatives are willing and able to share their reasoning, with minimal reason to withhold information. Participants need to be open to reflection. They must be able to conceptualize the comparison of the alternatives, to express and explore the explanations underlying their personal preferences.
A facilitator present	Participatory crossover analysis requires a facilitator who can handle the range of experience and expertise among participants. The facilitator maintains a safe environment for the participants to share and manages the process in such a way as to “deepen” the dialogue.

Step 4 is to facilitate the workshop. The main role of the facilitator is to quickly pivot from the identification of a preference to the underlying reasoning, aiming to increase the depth of the dialogue, drawing on participants’ expertise and experience. Participants are encouraged to identify and expand on influential factors, and how these affect their personal preferences. The facilitator informally guides discussions among the participants, while looking for (1) differences within the group and the origins of such differences (reasoning) and (2) consensus within the group on factors, reasoning and thresholds.

Step 5, the last step, is an evaluation process. The aims of the workshop are central herein. An evaluation can be a short recapitulation of the topics addressed and insights gained during the workshop, it can seek information from the participants on the perceived usefulness of the exercise, or the process itself can be evaluated. Additionally, an evaluation can aim to capture tangible outcomes, for example, the impact of the workshop in future decision-making.

TESTING THE FRAMEWORK

CASE STUDY AREA

We applied the framework to a case study in the Coal River Valley of Tasmania, Australia. The valley is a prime agricultural area in South-East Tasmania (Figure 3.2). Coal River Valley presented a situation that seemed to meet the first two conditions for participatory crossover analyses; that is, farmers' preferences regarding irrigation water sources were subjective, and there were several alternative water sources that could be compared (see Table 3.2).

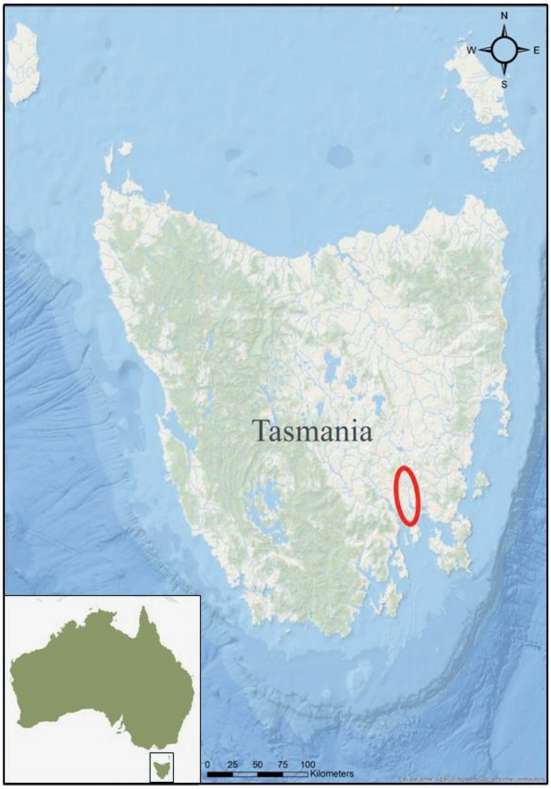

Fig. 3.2. Map of Tasmania, with the Coal River Valley in the red circle

The third condition, a dialogue situation, seemed to be present as well. In 1967, after devastating bush fires, the Coal River Products Association was established to improve cohesion among farmers. It can be seen as a community of practice, as defined by Wenger (1998). The association has been very successful. It was significant in encouraging farmers to try new crops and in building public and political support for irrigation schemes. The elected members of the association's executive committee represent the range of farm enterprises in the valley. All the members knew one another and had a history of knowledge sharing at monthly meetings addressing a range of topics. This gave us sufficient confidence that a dialogue situation could be created during a workshop with members of the executive committee as participants.

Farmers in the valley have gained experience with irrigation since construction of the Craigbourne Dam in 1986. Since then, the valley has changed more than anyone expected. The direct and indirect benefits of irrigation water were initially hugely underestimated, and farmers have developed their enterprises and intensified and increased their demand for labour (Lejda et al., 2009). Water demand in the Coal River Valley has thus been on the rise since 1986, leading to development of other irrigation schemes and recently to the use of recycled wastewater from neighbouring communities. The valley currently has multiple, very distinct water sources. We selected the oldest, cheapest and most expensive as relevant to discuss:

- Craigbourne Dam. The Craigbourne Dam is the oldest and first communal source of irrigation water that farmers invested in (Tasmanian Irrigation, 2019a).
- Reuse. Treated wastewater from nearby municipalities is by far the cheapest source of irrigation water. Wastewater from the nearby city of Hobart may offer a way to extend this water source in the future (Tasmanian Irrigation, 2019b).
- SE3. Water from the South-East Stage 3 project, provides the most expensive water of the State (Tasmanian Irrigation, 2017) and commenced operations in October 2015. It could sustainably provide much more irrigation water than at present, though the development of irrigation schemes depends on investments by both water users and the state (Tasmanian Irrigation, 2019c).

The Coal River Valley is held up as an example of the value of irrigation water for other areas in Tasmania (Lejda et al., 2009). In this regard, the Tasmanian setting is particularly interesting, as a long-term state policy objective is to increase agricultural output through irrigation and innovation (Tasmanian Irrigation, 2012a). This objective has propelled government initiatives to build new irrigation schemes to facilitate a transformation from dryland cropping to more intensified forms of irrigated agriculture. The approach taken in the design of new irrigation schemes includes a preliminary phase in which sufficient farmers must commit to buying water rights to cover at least 30% of the construction cost of the scheme. The other 70% is covered by the Commonwealth and Tasmanian governments. Commitments at the preliminary stage define the design of the scheme and the diameter, or supply capacity, of the irrigation pipes. As such, regional water availability is influenced by the decisions of water users, though they may be inexperienced in irrigation. It might therefore be beneficial for such farmers – and other stakeholders – to learn from the insights and reasoning of those with experience in making investment decisions on a new irrigation scheme in a comparable valley.

Experienced farmers will likely have garnered skills and information that influence their irrigation water demand and preferred water sources. What would be their preferred source of irrigation water if they had to make an investment decision now? Facilitating a discussion among experienced farmers about water sources might enable farmers to learn from one another. Their insights could provide valuable background information for investment decisions by other farmers, irrigation scheme designers and water managers.

INTERVIEWS

In October and November 2016, we conducted in-depth interviews with all farming members of the executive committee of the Coal River Products Association. These 13 persons were also intended to be workshop participants. The interviews lasted 1-2 hours and were geared towards exploring diversity and gaining a better understanding of farming in the Coal River Valley. The interview was set up in two parts. The first part was an accompanied survey to obtain the range of values for initial and operating costs of the various water sources. The second part was more open-ended, asking questions about the context and relevant factors when considering different water sources. We then introduced crossover analysis to each participant and discussed how water sources could best be compared in the workshop setting (Appendix IIA presents the interview guide).

The interviews were recorded and transcribed. Interview findings were used to check whether all the required conditions were met (Table 3.2) before proceeding to workshop design.

WORKSHOP DESIGN

The workshop was held in late February 2017 in a meeting room at University Farm, where they regularly meet. The 11 participants (2 members could not attend) were seated in a U-form, allowing them to see each other and the facilitator. The workshop was scheduled for an evening, and lasted 3 hours. It began with an introduction to the task, followed by two discussion sessions separated by a coffee break, and an evaluation and wrap-up.

The facilitator – the same person who had conducted the interviews – started the workshop by presenting the interview findings, specifically the range of values obtained for the relevant water source characteristics (Table 3.3). However, the perceptions of these values elicited in the interviews left two key questions unanswered: “Where do these different perceptions come from?” and “How do these differences in perceptions affect personal preferences?” This is what was discussed during the rest of the workshop. To reduce the risk that the discussion would be restricted by actual water accessibility, which varies within the valley, we used a hypothetical case where all three water sources were available and no on-farm infrastructure was yet in place.

The discussion centred on how much one characteristic of the most preferred water source for a type of enterprise had to change before personal preferences shifted to an alternative water source. The facilitator introduced this discussion with a topic question in the form, “How (much) does characteristic X have to change for you to switch from your initial preference to second best?” Participants were asked to indicate their initial crossover point via a PowerPoint add-in for polling called TurningPoint (Turning Technologies, 2019) and to indicate how confident they were about their crossover point on a personal worksheet. The facilitator then displayed the range and the average of the answers, which were anonymous.

Specifically, the five topic questions were the following:

1. How much does the cost price of water rights for SE3 water have to change before other water sources become relevant for perennial crops? Why?

2. How much does the cost price of the water rights for SE3 water have to change to make it the preferred water source for annual crops? Why?

3. How much value per megalitre (ML, or 1,000 m3) do you have to create to still prefer SE3 above alternatives? Why?

4. How much does the reliability of Craigbourne Dam water have to improve to become your preferred water source for perennial crops? Why?

5. What characteristics of reuse water would have to change for it to become your preferred source for perennial crops? Why?

To begin the discussions, the facilitator asked for a volunteer or picked someone, asking them whether the reported change in characteristics, on average, would lead them personally to change their preference. Why or why not? Other participants then expanded on this initial personal reasoning, adding to the discussion why their own crossover point did or did not differ. The facilitator allowed and even encouraged participants to raise the influence of other characteristics likely to influence the crossover point. After about 15 minutes, or when participants had no more differences to discuss, the facilitator concluded the topic by asking participants to enter their final crossover point in TurningPoint. Again they were asked to record their level of confidence about their crossover point on their worksheet. This time they were also asked to record whether their answer had changed and if so why.

EVALUATION OF THE WORKSHOP

The workshop was recorded with a voice recorder and transcribed verbatim. A note taker took notes during the process on the usefulness of the discussions in generating transferable content and knowledge. To address the theoretical component, or the process, the note taker recorded observations on group dynamics, particularly engagement, attitudes and signs of problems. A twofold evaluation process was employed. First, to provide preliminary feedback on the process, we asked participants to evaluate the workshop and their learning. For this they filled in an evaluation sheet with both open and multiple choice questions on topics such as their level of comfort in talking honestly about their preferences and personal reasoning, the perceived usefulness of the workshop for themselves and others and the pace of the workshop (see Appendix IIB for details). More detailed follow-up came later in the form of telephone interviews two to five weeks after the workshop. These interviews focused on the process and on learning-related outcomes and lasted between 15 and 25 minutes. They were recorded by one of the authors, transcribed verbatim and analysed thematically. The questions addressed the added value of the crossover concept and the value of the group discussion. Participants were asked what they remembered as particularly useful or interesting and if and how the workshop had changed their thinking and decision-making, as well as the perceived usefulness/value of the discussion to themselves and to others. Appendix IIC presents the guide for the telephone interviews.

3.3. RESULTS

This section examines the results of the exercise. These are presented by first regarding the practical research component, that is, assessments and perceptions of the alternative water sources. Then, results are examined regarding the process, in other words, the theoretical component of the case study.

PRACTICAL COMPONENT: CASE-SPECIFIC RESULTS ON WATER SOURCE PREFERENCES

INSIGHTS FROM THE INTERVIEWS

All participants mentioned cost, quality and reliability as important factors, or “characteristics” as participants called them, in their water source preferences. Table 3.3 displays the range of values mentioned for the most relevant characteristics. Costs were divided into upfront capital and annual running expenses. The annual component of SE3, which is delivered under pressure (no pumping costs), includes a fixed cost independent of use and a variable cost in relation to the water supplied. The variable cost further depends on the farm’s location in the irrigation scheme.

Some participants indicated that sources varied in “manageability”, which is related to the ability to trade water with neighbours and flexibility of use (water may be available on demand or be provided as a constant flow over the summer). Some of the relevant characteristics could be defined in different ways, and this might have influenced personal preferences. For example, water quality encompassed an array of parameters and a range of threshold values relevant to suitability for the purpose of an enterprise.

Table 3.3. Water sources and range of values for the most relevant characteristics

		Craigbourne Dam	Reuse	SE3
Cost	Capital cost per ML (water rights)	$1,000-$2,500	$0	$2,500-$2,700
	Annual cost per ML at farm gate plus pumping cost to put it in on-farm dams	$105 plus pumping (up to $150)	$10-$70 plus pumping (up to $150)	$135 fixed + $170-$211 variable
Quality		Variable but often too poor for sensitive	Comes with restrictions on	Almost drinking water quality
Reliability		60-90%	80-100%	95% (according to Tasmanian Irrigation)

Note: ML = megalitre, or 1000 m^3.

Participants linked their water source preference and willingness to pay to the crop they grew with the water. In some cases, non-monetary factors were also in play, and these went some way in certain cases towards bridging the gap between the cheapest and most expensive sources, possibly making the latter worthwhile. One participant said, *"The two characteristics I find most important are high reliability and high quality. For that, I pay whatever I need to pay to irrigate my orchard."* Another participant said, *"I will deal with whatever reliability or quality, but I am really focused on cost. Cost is actually all I look at; if it gets higher than I want to pay, I will not grow a crop and will sell my stock."* These two quotes represent opposite ends of a spectrum. Based on the recommendations of the participants, we divided the farm enterprises into three types: livestock, annual cropping and perennial cropping. As Table 3.4 shows, these enterprises have relative differences in their demands regarding water source characteristics.

Table 3.4. Relative differences of demands for water source characteristics as discussed during the interviews, based on farm enterprise type

	Livestock	Annual cropping	Perennial cropping
Cost (willingness to pay)	Low	Middle	High
Quality demand	Low	Middle	High
Reliability demand	Low	Middle	High
Manageability	High	Middle	Low

We also learned that the valuations assigned to characteristics of both water sources and enterprises were subject to change. Indeed, over the years, most participants' willingness to pay for water had evolved. For example, one participant stated: *"I remember when water from the Craigbourne cost $15/ML and it went to $20/ML and we all thought it was too dear. Sometimes you have got to pinch yourself and realise that I'm about to spend $250,000 just to get access to 50 ML of water. If someone would have told me this 10 years ago, I would have thought he was living in fairyland but perceptions change. If I tell other growers about the reality of irrigation water they often don't believe me. However, you really need a crop that generates the value that covers the costs."*

INSIGHTS FROM THE WORKSHOP

Our insights from the workshop are focused on the discussion rather than the specific values assigned to the crossover points or their changes. Nonetheless, Appendix IID provides an indication of the crossover points. Participants' reasoning is fundamental in determining the crossover points and therefore likely to be more transferrable and relevant to other farmers, water managers and policymakers than the crossover points themselves. Crossover points, and even changes in crossover points or confidence levels before and after the discussions, may simply be an artefact of the facilitation process (e.g., providing a better understanding of the question). These results are clearly subject to change, case-study dependent and by no means representative. There is also a risk that crossover points may be misinterpreted when lacking context.

Our reporting of the discussion focusses on reasoning and insights with a summarizing sentence at the beginning of every paragraph, accompanied by a reflection on the aims in Table 3.1 at the end of every paragraph.

What is water worth?

The first three questions of the workshop focused on willingness to pay for water. Participants discovered that within the group there were distinct ways of accounting for the various components making up the total cost of water. These contributed to very different views on investments in water rights. The factors considered, the way these factors were brought together, and the assumed cost of the different factors turned out to be subjects of personal perception. Some reported seeing water as a capital cost and spread it over a period of least 10 years. Others just considered the interest rate of their loan to procure water, which would lead to a higher willingness to pay, compared to participants who integrated the cost of water rights into their yearly budget, similar to the purchase of an irrigator or a tractor. Some thought that water would increase in value, while others disagreed. Some expected interest rates to go up in the future, making water more costly if you had to borrow from the bank to finance it. Participants also disagreed on whether a bank would lend money to buy water or not, and about whether buying water is equivalent to buying more land. These different views suggest the usefulness of following up the workshop with a more quantitative study to provide information or advice about strategies to integrate the cost of water rights into a yearly budget.

After several minutes' discussion about the minimum value that needs to be generated per megalitre to still prefer SE3 over alternatives, one participant came up with a rule of thumb. He reasoned, *"For me, it would be $6,000/ML. I base that on $300 annual cost and 10% of the cost of the water rights, another $300, and so $600/ML. I use the rule of thumb that the cost of water should be around 10% of the budget to grow a crop. If you grow fruit, I reckon that if you need more than 10% for your water you go backwards because you have a lot of other expenses that come in as well; wages are huge costs for me, investment in capital, fertilizer and marketing."* This very explicit line of reasoning began with a discussion on the robustness of preferences, which unfolded into exchanges about this personal rule of thumb. Some participants agreed that although they had not considered the rule before, the 10% was a good figure to aim for. Others reasoned that this figure might be applicable to fruit trees but not annual crops, as water is just one of the many costs involved in growing a high-value crop such as fruit trees. For most annual crops, the percentage spent on water could be greater as there are fewer other inputs. Both the average value of crossover points and the level of confidence (how confident participants were about their crossover point) increased during the discussions. By explaining and exploring the specific rule of thumb, participants gained a better understanding about where differences in willingness to pay for water came from.

There was strong consensus in the group about minimum value generation. Based on their experience and the scale of cropping in the valley, participants agreed that it was impossible to make a profit from either livestock or traditional annual crops (e.g., cereals) using SE3 water. Use of this water source would thus involve a change of enterprise to a high-value crop, preferably *"with a contract in your pocket"* before investing in water. They did note that the situation might be different for larger farms, as they knew of farmers growing annuals with high-value water in nearby valleys. The finding, based on end-user experiences, that investment in high-value water would require a change in enterprise and everything that comes with such a change, are very relevant for other farmers, irrigation scheme designers and water managers.

Where does reliability come in?

There seemed to be consensus among the participants about the minimum reliability needed for perennial crops: irrigation water bought for use on perennials needed to be at least 95% reliable. For some, preferences were very robust: Craigbourne Dam water would never be suitable, because the quality and the reliability of Craigbourne water was not good enough. The crossover points on reliability and the associated confidence levels stayed the same during the discussions. However, there was much debate about the meaning of reliability and how scheme management affects reliability. One participant said that if there was a guaranteed minimum supply to at least protect your trees from dying, there would be a crossover point somewhere. Another argued that if water was cheap enough, you could buy water rights to have *"up your sleeve"* if your main source was restricted. Others pointed out management benefits of Craigbourne Dam compared to SE3: (1) *"The reality is that the delivery process makes a big difference. When there is not enough water for everyone, water trading kicks in. We learned in the last 20 years that during a drought some people end up buying water and other people sell, probably making more money than they would have if they applied it to their low value crop. Craigbourne allows you to buy the yearly water rights from others that do not need it as much."* (2) *"Craigbourne is a public dam that is holding the water for you. If you buy SE3, you still need a big farm dam, so you are duplicating what is already been done for you."* (3) *"SE3 gives you water during 180 days a year while you can order Craigbourne water in a large volume delivered over a short time."* (4) *"Craigbourne actually pays for evaporation while with SE3 you pay for it yourself."*

Differences in experiences and in the practical meaning of reliability influenced how participants factored this characteristic into personal decision rules. A preference for other sources seemed very robust if high reliability was demanded but could not be guaranteed.

What restricts reuse?

When discussing reuse water, participants agreed that restrictions and regulations needed to be reconsidered, as they were currently hampering uptake. However, they did not agree on which characteristics of reuse water would have to change for it to become the preferred source for perennial crops. Various inhibitive factors were mentioned for reuse water: costly regulations on groundwater monitoring, restrictions regarding empty creeks, regulations demanding that fully grown crops be "washed" with non-reuse water before harvest, and differing regulations for the domestic and international market. Some participants thought that restrictions on reuse water were different in mainland Australia.

Allocation of reuse water was another issue raised as this source is allocated in a year-to-year procedure instead of long-term water rights. Such flexibility in allocation of water might benefit particularly the water provider, as participants said they would rather know their allocation for at least five years, in order to plan ahead. This indicates that there is room to improve supply management of reuse water, and a better understanding of the costs and restrictions might influence farmers' willingness to pay. However, "optimal" management is influenced by the perspective taken, as what is best for farmers might not be best for water managers.

THEORETICAL RESULTS: THE PARTICIPATORY CROSSOVER ANALYSIS PROCESS

Participants differed in their abilities to provide or expand on explanations for their initial crossover point. Some seemed initially unable to conceptualise their reasoning. When asked about their initial crossover point, they answered something like, *"that is just what I think".* Nonetheless, after others explained their personal reasoning, they found that they actually could react, compare and define where and why certain arguments did or did not apply to them. Here, the facilitator played a significant role by encouraging participants to explain their "why".

During the course of the workshop, participants began asking each other more and more questions. The coffee break proved important here, as discussions went on, reflecting, explaining and comparing – sometimes ending in an agreement to disagree. Once participants began asking each other questions, the discussion really benefited from differences in background and fields of expertise.

The evaluation indicated that the participants felt willing and able to share their reasoning and listen to each other. They felt comfortable talking honestly about preferences and personal reasoning, and they were confident that others had been honest during the process (Appendix IIB). Only one participant did not take part in the discussion, explaining during the later telephone interview that they did not feel comfortable talking, but that listening to others had been very interesting and meaningful. The facilitator and workshop design thus succeeded in providing an environment in which participants were at ease and able to contribute and learn.

Though participants agreed that the process as a whole had been interesting, their opinions were more varied on whether it would influence their decisions. Some said they were already committed to a particular water source, and others had been working in irrigated agriculture for so long that such a short workshop seemed of little influence for them. However, most participants did indicate that the workshop would have some influence on their decision-making, as it contributed to the gradual development of their perspective or intuitive understanding of options, values and alternatives.

3.4. IMPROVEMENTS AND LIMITATIONS

GROUP COMPOSITION

In the case presented here, participants varied in their backgrounds and fields of expertise within a farming context. Nonetheless, the group can be considered homogenous as all were experienced irrigators with the same goal: optimising water availability on their own farm. Even more, the participants had a history of knowledge sharing, knew each other personally and trusted the legitimacy of the process. Thus, the presented case should be situated in the lower left quadrant of Figure 3.3.

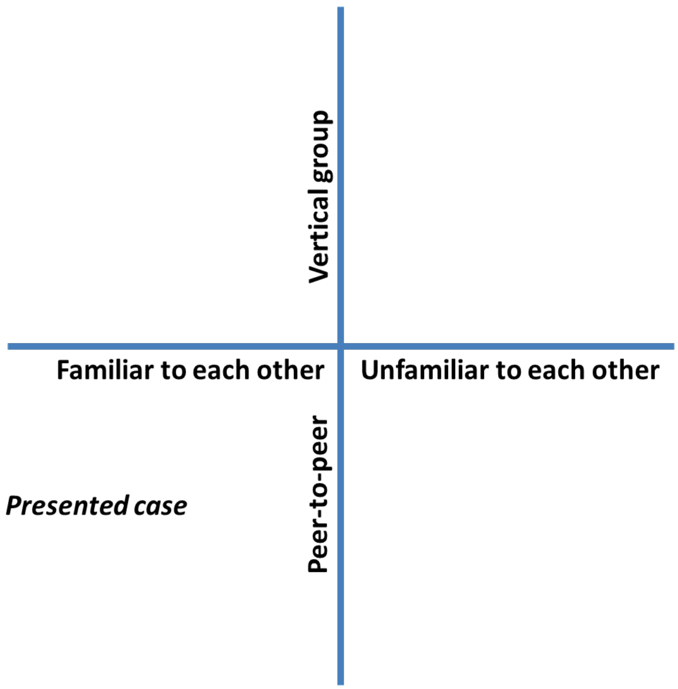

Fig. 3.3. The presented case study took place with a homogenous group that knew each other beforehand

Due to the nature of the Coal River Products Association as a community of practice, participants might have been particularly interested in each other's reasoning beforehand and therefore more open and willing to learn than in cases without a community of practice in place. It would be valuable to test the framework with a more heterogeneous group, in which preferences are based on different backgrounds, perspectives, expertise and especially, different scope of involvement in the issue being discussed. An example discussion topic in the Coal River Valley could be, "Under what conditions is reuse water the most suitable source to increase water availability in the valley?" Policymakers, water engineers and farmers could all be involved, providing a heterogeneous group. Such a workshop could allow stakeholders to "learn together to manage together", which is how Pahl-Wostl et al. (2007b, p. 3) define social learning.

There is widespread agreement in the social learning literature that focusing on "how perspectives influence problem definition and preferred outcomes or solutions" is fundamental when managing natural resources like water (e.g. Leith et al., 2017; Mostert et al., 2008; Pahl-Wostl et al., 2008a; Tompkins & Adger, 2004). Such a discussion would be situated in the top left quadrant of Figure 3, as most stakeholders would know each other. In such a setting, the dialogue situation changes in that specific efforts would be needed to ensure that our third condition – a dialogue situation (Table 3.2) – still holds. In a more heterogeneous group, legitimacy of the process might be more contested, and participants might have incentives not to share information. Crossover point determination could also be used strategically, for example, in discussing willingness to pay for water in a negotiation setting. In such a setting, the filled in crossover points become even less relevant. However (qualitative) reasoning might be less prone to strategic use and may still provide a solid basis to help clarify diverse personal preferences. As a method for understanding the reasoning underlying preference outcomes, participatory crossover analysis could become a valuable tool to facilitate social learning, especially in early phases of participatory processes.

All of our participants indicated that the outcomes of the workshop would be of interest to other farmers, but some mentioned limitations as well. In particular, actively taking part in a discussion was said to provide a greater opportunity for learning than reading about the outcomes of a discussion that others had. Participants acknowledged that their own learning about how water can be used was a slow and iterative process. Most workshop participants benefited from lessons gained over years. As one participant explained, *"When I started farming, I was not irrigating. Then, the Craigbourne scheme came along, basically putting water on my farm for nothing. You just bought your irrigators and started. So, we did not think about the benefits and how much this water is worth. We already had a start. We all were doing something and changed our focus when the water came along. Nowadays, it is very different; you have to buy water and all the infrastructure up front. If Craigbourne would have had the characteristics that SE3 water has today, I wonder if we would have a scheme in the valley. Would we have dug deep in our pockets for it? I wonder if we would be growing crops at all. The focus on perennial crops and with that our water demand, only went up after years of experience."*

This statement led to a discussion in which other participants suggested that their *"slowly gained"* experience could be used to speed up the learning curve for others through crossover discussions. In the Tasmanian setting it might be interesting to bring experienced irrigators together with dryland farmers from valleys with irrigation potential to exchange knowledge and ideas. This could be facilitated by a crossover workshop. Both experienced and inexperienced irrigators could explore and explain their reasoning together, while acknowledging differences in farming context, as in the bottom right quadrant of Figure 3. This approach would be suitable only for groups in which participants are willing and able to share, explain and listen.

WORKSHOP STRUCTURE

A workshop structured on an explicit model of costs and benefits would have had other objectives and hence produced completely different results. This would likely have led to a dissimilar learning experience for the participants. When asked for recommendations to improve the workshop, some participants did suggest providing a cost model calculating at what point it is “worth it” to invest in water, like the crossover model of Guillaume et al. (2016). Such tools exist in many forms and are being applied, for example, by agronomic consultants to assist individuals and groups in making investment decisions. Although we acknowledge the value of quantitative approaches, our qualitative approach pursued different aims (Table 3.1).

The added value of the approach presented here is in encouraging participants to challenge established beliefs, to be open and discuss their considerations candidly with each other. It was not aimed at objectively determining the crossover point where a farmer would turn a profit; it was about learning what a range of farmers considered when faced with an investment decision and where differences in preference came from. Thus, the most appropriate approach would be highly dependent on the aims. Combined approaches could also be applied as combinations can complement each other (see e.g. Alamanos et al. (2018)). A more cost-oriented crossover discussion could be used as a follow-up, especially as workshop participants were found to have distinct strategies for integrating the costs of water in their yearly budgets. Such a workshop could make use of an interface that visualises the consequences of assumptions on cost and benefits on rankings of alternatives, see Guillaume et al. (2016).

Participants widely agreed that some of the framing questions in the workshop were confusing. This was in part because some were ambiguous, but also because the idea of discussing a crossover point based on a single variable was initially confusing. During the workshop, the facilitator made clear that the single variable merely defined the angle of the discussion, without precluding other variables from being mentioned. Then, the discussion moved quickly from the observation that selecting preferred options depends on many variables, to articulating those variables and, over the course of the workshop, to interrogating each other’s thinking and analyses as to why some variables were more important than others. This indicates a need for the facilitator to better explain the angle of the discussions at the start of the workshop.

CAPTURING USEFULNESS TO PARTICIPANTS

Part of the evaluation focused on the workshop's perceived usefulness to participants. Eight participants indicated in the evaluation that the crossover framework provided a valuable way to support group discussion. Or, as one of the participants stated, *"I liked discussing irrigation water sources this new way."* Nine participants said that the process had been valuable in influencing their thinking about complex water investments. During the phone interviews, most said that they would recommend the workshop to other farmers and agreed that the content of their discussion would be interesting for others. An avenue for future research would be to seek improved means to capture different forms of usefulness and outcomes of workshops in similar complex decision-making contexts.

Participation does not necessarily mean that learning is occurring (Collins & Ison, 2009), and evaluating the outcomes of participatory workshops aimed at learning is widely recognised as challenging (Cundill & Rodela, 2012; Kenter et al., 2016b; Rowe et al., 2008). Participants might find it difficult to indicate that they "learned something" (e.g. Dryzek, 2006), and might find it even harder to make explicit "what" they learned and how it will influence future investment decisions. In our evaluation, we therefore asked the participants whether the workshop was useful enough for them to recommend it to others or even to participate in another one. If the answer was yes, the workshop was considered likely to have produced new learning or insights. Our evaluation confirmed this, though participants could not directly link their learning in the workshop to specific decisions.

Reflecting on their personal reasoning and learning from and with others to understand why crossover points differed turned out to be both relevant and useful. This learning is in our case decoupled from decision making. Decoupling learning from decision making allows participants to bridge divides, moves the discourse away from strategic calculative reasoning and improves dialogue conditions (Dryzek, 2006; Kanra, 2012).

Participatory crossover analysis deliberately avoids trying to simplify the context and come to a decision that is "best". However, it still asks participants to examine and verbalise their decision-making process. Consciously comparing between alternatives can lead people to focus on an incomplete set of attributes (Wilson & Schooler, 1991), and having to verbalise one's reasoning can produce even larger biases (Schooler et al., 1993). Besides, focusing on computable factors may be insufficient when trying to solve complex problems (Carpenter et al., 2009). Research in social psychology clearly demonstrates that the more complex a problem is, the less likely it is that conscious thought can contribute much as the subconscious is much better at associating, integrating, elaborating and weighing in complex situations (Dijksterhuis, 2007). On the other hand, intuitive thinking (doing what feels best) is also prone to many biases and that conscious thinking (thinking slowly) is often necessary to make the "right" decision in complex situations (Kahneman, 2011). Our evaluation results indicate that part of the perceived usefulness lay in the linking of conscious and intuitive thinking. We therefore suggest that research connecting participatory crossover analysis to the social psychology domain might be particularly fruitful to further improve the framework.

3.5. CONCLUDING REMARKS

The participatory crossover analysis framework, as presented, applied and evaluated in this chapter, shows promise in supporting group discussions. We applied the framework in a setting where participants knew each other and shared the common goal to optimise water availability on their own farm. In the case study, different water sources, with distinct characteristics, were available. Participants engaged in a dialogue exploring the personal reasoning which led to their individual water source preferences. Sharing and integrating local knowledge is said to be key for improving water management and governance (Pahl-Wostl, 2017). In an informal and explorative setting, participants shared their knowledge and encountered the distinct ways of accounting for the characteristics that determined their water source preferences. The crossover questions focused on the cost, reliability, quality and manageability of three water sources. Participants discussed (1) how the factors, or "characteristics", under consideration would have to change, to switch personal preferences, in other words, for a crossover point to occur; (2) why and how their own crossover points differed from those of other participants; and (3) how participants' reasoning changed over time.

From the start we were deliberately specific about our aims in organising a participatory crossover analysis (Table 3.1) and the conditions under which such a discussion could gainfully take place, as the setting was recognised as influencing the process (Table 3.2). What is required to obtain a productive dialogue situation (condition 3 in Table 3.2) warrants further exploration, for applying the framework in different case study settings.

Our results support the argument that the crossover point concept encourages participants to engage in a dialogue that elicits and explores the personal reasoning underlying preferences and helps explains nonuniformity in investment decisions. During the workshop, participants had the opportunity to share their knowledge and learn from others. A policy implication is that such discussion could provide valuable information and insights into the factors that influence personal preferences. Such information and insights can be of value both to the participants and to others. In this case study, particularly, farmers with the opportunity to become irrigators, as well as water managers and policymakers. Peer-to-peer workshops, such as the one described here, can enrich the knowledge of potential water buyers so that they can make better informed investment decisions. Most workshop participants evaluated the overall process as worthwhile. What they learned, they said, would feed into the gradual development of their thinking and intuitive understanding of irrigation water sources. Moreover, they understood better the reasoning underlying their personal preferences in this regard.

This case study showed the feasibility of applying participatory crossover analysis. Based on the positive evaluations of participants, we believe that the framework merits further development. In particular, we recommend three future research areas when applying the framework in different settings: zooming in on the contexts in which participatory crossover analysis is applicable, assessing the outcomes, and exploring how best to achieve social learning.

4. SHARING REASONING BEHIND INDIVIDUAL DECISIONS TO INVEST IN JOINT IRRIGATION INFRASTRUCTURE

This chapter is published as Nikkels, M. J., Guillaume, J. H. A., Leith, P., & Hellegers, P. J. G. J. (2019). Sharing Reasoning Behind Individual Decisions to Invest in Joint Infrastructure. *Water,* 11(4), 798.

In Tasmania, Australia, development of joint irrigation infrastructure depends on individual farmers' investment decisions. In this case, the development of infrastructure is ultimately a group decision, which benefits from individuals having a common understanding of the various values at stake. A farmer's valuation of water and decision to invest is based on their current knowledge and understanding. Sharing personal reasoning behind individual decisions is a promising approach to build this understanding. This chapter demonstrates how the question "under which conditions would you - the individual farmers - invest?" offers farmers the opportunity to reveal a broader set of reasoning than just financial or monetary factors. This chapter explicitly implements the concept of participatory crossover analysis in a water valuation setting. The participants' willingness to pay, in the form of crossover points, is presented as a set of scenarios to start an explorative discussion between irrigators and non-irrigators. Feedback during evaluation showed the workshop enabled sharing of new information, improved understanding of reasoning behind personal decisions to (not) invest in extra water for irrigation, and led to more respect for the others and the decisions they made. As expected, reasoning goes beyond economic concerns, and changes over time. Life-style choices, long term (intergenerational) planning, perceived risks, and intrinsic motivations were discussed as factors influencing water valuation. Simply having a (facilitated) discussion about the reasons underlying individual willingness to pay seems to be a useful tool for better informed decision making about joint irrigation infrastructure, and is worth testing in further case studies.

4.1. INTRODUCTION

Building irrigation infrastructure is a long term investment with potential to transform a community. The size and design of the infrastructure is a critical decision that needs to be made based on the best information possible, not just about water resources, but also about the values of the community. In the 20th century, decisions about irrigation infrastructure were dominated by cost-benefit analyses from the funders' perspectives, notably national governments and international donors (Turral et al., 2010). There is, however, growing recognition that non-monetary aspects need to be considered, and that greater participation by stakeholders would improve consideration of these aspects (Garrick et al., 2017; Graversgaard et al., 2017; Harou et al., 2009).

In particular, there now is a trend in which farmers co-invest with (local) governments to improve the water system (Gleick, 2003; Tasmanian Irrigation, 2012a; Ward, 2010; ZON & DHZ, 2015). Local stakeholders then need information to help them decide whether investment in an (adaptive) measure is "worth it". Relevant questions are, what information do they need and how do they get it?

In this chapter, we first discuss existing techniques for valuation of water. We then briefly review the recent concept of participatory crossover analysis, which involves identifying conditions in which a decision would change (a crossover point scenario) as a starting point for discussion. The question "under which conditions would you – the individual farmer – invest" offers farmers the opportunity to reveal a broader set of values, beyond the financial or monetary. In a water valuation context, this idea can be implemented by eliciting individual willingness to pay (WTP) of a group of participants, which is then used as a set of scenarios to start a group discussion with peers.

Following this idea, we build on participatory crossover analysis to design and implement a peer-to-peer learning workshop around WTP scenarios. We make use of a case study area in Tasmania, Australia in which the recent design of an irrigation scheme was determined by individual farmers' decisions to invest in irrigation water during the construction phase. In a workshop setting, we use the value of water as a concept to encourage discussion of the reasons underlying individuals' WTP for irrigation water, and hence decision to invest. We ultimately aim to enrich the participants' understanding of the value of water, so that they can make better informed investment decisions in the future.

VALUATION OF WATER

A farmer's decision to invest in joint irrigation infrastructure is based on their current knowledge and understanding regarding whether "benefits" will outweigh the "costs", in either the short or long term, based on not only monetary but also e.g. emotional and social factors (van Duinen et al., 2016). Benefits and costs include impacts on others and system feedbacks due to others' actions, such that sharing personal reasoning is expected to be useful for farmers to build a common understanding of the various values considered in decision making (Šūmane et al., 2018) and achieve a more comprehensive valuation of water. Valuation is "the process of expressing a value of a particular object or action" (Costanza, 2000; Farber et al., 2002). Valuation can happen both implicitly and explicitly and sits at the core of investment decisions. Water valuation means "expressing the value of water, including related goods and services, in order to support their allocation and sharing" (Hermans et al., 2006a).

Valuation of water in agriculture is known to be problematic. Various authors have argued that valuation can be biased or incomplete, e.g. (Birol et al., 2006; Hermans et al., 2006a; Turner et al., 2004; Ziolkowska, 2015). These arguments follow from the understanding that water has economic, environmental, cultural, religious, and social dimensions (Davidson et al., 2009; Garrick et al., 2017). In addition, values will often change over time (Wei et al., 2017) and include both use (e.g. for irrigation) and non-use values (e.g. swimming and aesthetics) (Hoekstra et al., 2001; Turner et al., 2004). These multiple, personal and changing values of water are also discussed and reflected upon in ecosystem services literature; see e.g. (Costanza et al., 1997; Derkzen et al., 2017; Johnston & Russell, 2011).

There is ample evidence (van Duinen et al., 2015; Veraart et al., 2017) that investment decisions in water for irrigation deviate from those predicted by microeconomic models relying on a rational representative economic agent maximizing its utility function under conditions of perfect information and in the absence of biases or unequal power relations (Raworth, 2017). Farmers have their own specific reasons for making investment decisions, either implicit or explicit (Öhlmér et al., 1998). Water valuation literature thus suggests a need to empirically capture what stakeholders care about.

There are indirect and direct inductive techniques to tackle this challenge and determine the value of water (Turner et al., 2004; Young & Loomis, 2014). Indirect techniques depend on observations to deduce values. They include: observations based on market transactions, derived demand functions, and hedonic pricing. Indirect techniques are only able to estimate values and are considered suitable for valuing those water resources that are marketed indirectly (Birol et al., 2006). Direct valuation techniques, such as contingent valuation methods, elicit preferences directly by questioning individuals regarding their WTP for water (Bateman et al., 2002). Contingent valuation provides a means to gain insights into the personal value determination of water in monetary terms (Venkatachalam, 2004). It is not a valuation of water itself (so called intrinsic value) (Pearce & Seccombe-Hett, 2000). Contingent valuation is widely applied to assess the monetary value of irrigation water, see (Knapp et al., 2018; Mesa-Jurado et al., 2012; Zuo et al., 2015).

An example providing a broader view on value is provided by Hermans et al. (2006b). They describe a method called “the mosaic of values” in which stakeholders and water professionals (in their case researchers) jointly assess the various values of water. The authors identify indicators for economic values, social values, and environmental values, and examine differences between farming systems. Water valuation with stakeholders provides a means to share insights and incorporate the knowledge and expertise of participants. We agree with Hermans et al. (2006a) that, to support water resources management processes, existing valuation approaches need to be complemented with methods that move stakeholders centre stage. In this way, water valuation is part of a process of learning with and from each other. Doing so addresses the request of the UN High Panel on Water (World Bank, 2017) and Garrick, et al. (Garrick et al., 2017) who call for water valuation methods that address the multiple and personal values of water.

CROSSOVER POINT SCENARIOS AND DISCUSSION OF WTP

In parallel to water valuation literature, there is emerging work on participatory methods that aim to support water management processes (Newig et al., 2008; Scholz et al., 2014a). An example is the use of crossover point scenarios as a way of prompting discussion in which participants can learn about each other's perspectives on a particular problem. Crossover points are conditions in which a decision would change. At that point, an individual equally prefers two alternatives, for example whether or not to buy water; it is a point of indifference. The crossover point is therefore a natural scenario for prompting discussion about why a decision is made (Guillaume et al., 2016). Analysing crossover points in a group setting focusses on two key questions; 1) When – i.e. under which conditions - does an alternative out-favour another and 2) What drives this (personal) preference? Participants are encouraged to think beyond their day to day practice and ask themselves questions including: Under which conditions would I change my opinion or preference, and no longer do what I am currently doing? (Why) has this crossover point changed over time, and what do I expect my future crossover point to be?

In particular, in Chapter 3, a fully workshop-based method called Participatory crossover analysis was developed. The main aim of this method is to engage participants in a dialogue that explores the personal reasoning through which preferences are defined, with the aim of learning from and with each other. Sharing personal perspectives within a group sits at the core of social learning processes (Bos et al., 2013; Pahl-Wostl et al., 2007b; Reed et al., 2010).

The concept of discussing a crossover point scenario translates directly to discussing a WTP scenario; WTP is a crossover point describing (monetary or financial) conditions in which an individual would change their decision on whether or not to invest. Given that valuation is a central concept in an investment decision, the idea of discussing WTP scenarios in a workshop promises to similarly engage participants in a dialogue that allows them to learn from each other by sharing knowledge and information with their peers. In the discussion, participants explore the factors that change their investment decision. Differences in crossover points within the group become the basis for a facilitated dialogue about reasoning, and exploring where differences come from.

The focus on enabling dialogue potentially provides a powerful tool to investigate the multiple and personal values of water that the UN High Panel on Water (World Bank, 2017) calls to address. In addition to direct monetary costs and benefits, the discussion elicits non-monetary values, and then also digs deeper to understand the assumptions and personal reasoning underlying these values. This approach therefore builds on contingent valuation literature by focusing on the processes that underlie responses, as is recommended by Burgess et al. (1998). Rather than obtaining a single estimate of value for an individual at a point in time, it provides an understanding of the factors affecting variation in values within a group and over time, anticipating non-stationary conditions over the life of an irrigation scheme.

By taking a dialogue facilitation approach, it fits with a grounded theory tradition (Urquhart et al., 2010) and avoids prematurely introducing the water valuation expert's preconceived notions: there is no predefined model of value as there would be when starting from a cost-benefit analysis, and not even predefined categories of costs or benefits, as there would be in a structured survey. We would like to emphasize here that the intention is not to find a "true" WTP or "right answer", as is often the aim of contingent valuation. The idea is to use WTP purely as a starting point for discussion, providing an opportunity for participants to explore their own reasoning and compare with others; the process aims to help participants to build confidence and capacity to make better informed decisions.

This chapter builds on previous work by explicitly implementing this concept in a water valuation setting, focused on WTP. The following case study therefore explores the potential for using a peer-to-peer learning workshop based on WTP scenarios as a means for a group of farmers to reveal and share a broad/rich set of reasoning, with the ultimate purpose of informing their investment decision in joint irrigation infrastructure.

4.2. MATERIALS AND METHODS

CASE STUDY CONTEXT

The Tasmanian Government has the ambitious goal to increase the annual value production of the agricultural sector from $1.8 billion in 2012 (Australian Bureau of Statistics, 2013) to $10 billion by 2050 (DPIPWE, 2017). New irrigation schemes facilitate intensification and transformation of the Tasmanian agricultural sector. Tradable water rights and user charges are used as instruments to manage demand for irrigation water (Hellegers, 2006). The irrigation schemes currently developed and managed by Tasmanian Irrigation (TI) are designed to last 100 years, deliver water at a reliability of at least 95%, and are built to satisfy current demand in each region of Tasmania. The approach of irrigation scheme design in Tasmania includes a pre-feasibility phase in which farmers must commit to buying water rights to cover at least 30% of the scheme's construction costs. Australian Commonwealth and Tasmanian Governments cover the remaining share. The aggregated user commitments define the design of the scheme including the diameter of the irrigation pipes, and hence supply capacity (Tasmanian Irrigation, 2012a).

The South East Irrigation Scheme (SE3) provides the most expensive water of the State (Tasmanian Irrigation, 2017) and commenced operations in October 2015 (Tasmanian Irrigation, 2019c). SE3 services agricultural enterprises around the townships of Tea Tree, Campania, Orielton, Pawleena, Penna, Sorell, and Forcett in the South East of Tasmania (Figure 1). Current production is diverse; it includes annual crops (from barley to lettuces), perennial crops (from Lucerne to cherries), and livestock (from wool to fattening organic cattle). Close proximity to the Hobart airport caters for high value export crops.

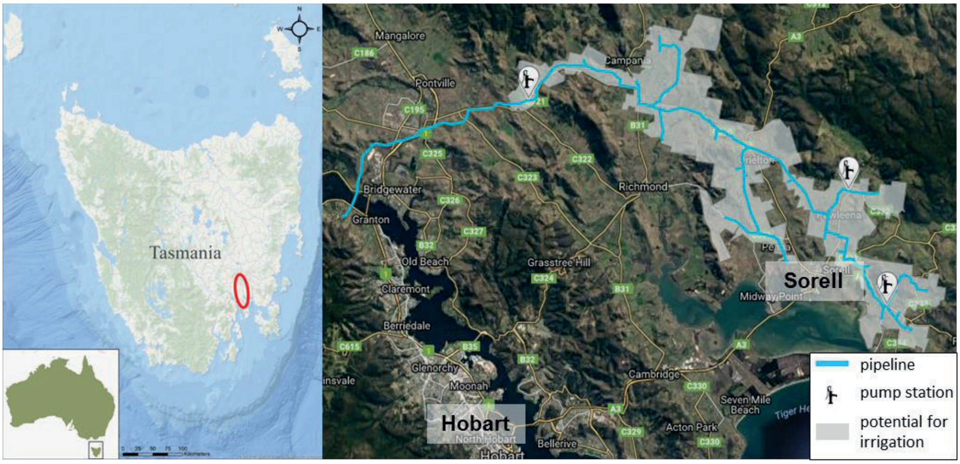

Figure 4.1. Case study area of the South East Irrigation Scheme Phase 3 (SE3) district in southeast Tasmania, Australia. The SE3 image is adjusted from (Tasmanian Irrigation, 2019c).

SE3 water is sourced from the River Derwent, approximately 30 km from the first outlet. A pipeline distribution network delivers pressurized, almost drinking quality water throughout the SE3 district with a reliability of at least 95%. According to a TI irrigation scheme manager, almost 400 landowners were contacted directly during the 2012 water sales period of SE3. By January 2018, 62 water entitlements were sold. Based on the aggregated commitments in the pre-feasibility stage, the SE3 scheme now has the capacity to supply 3000 ML (3×10^9 litres) of water during a 180-day summer delivery period (October – March). In addition, 3000 ML could be supplied during a 180-day winter delivery period (April – September). At the time of writing, there are still a limited number of summer water rights available in parts of the scheme (location and pipe diameter dependent) but no winter rights are offered for sale (yet). The (one-off) cost of a water right is currently $2700/ML plus a yearly cost with a fixed component of $140/ML and a variable (delivery) component of $178-$220/ML (Tasmanian Irrigation, 2017).

In the adjacent Coal River Valley, farmers from different backgrounds are united in a community of practice which gathers regularly (www.coalriverproducts.com.au).

Connecting with peers is widely acknowledged to positively influence learning (e.g. Pretty & Ward, 2001; Wenger, 1998). In the SE3 district, there is currently no such formal platform or association where irrigators and non-irrigators exchange ideas and learn from each other. There are various enterprise associations (e.g. Wine Tasmania, Fruit Growers Tasmania), but they bring together farmers within the same business and lack a district focus. There is however an irrigation committee, representing irrigators in meetings with TI. After a workshop organized in February 2017 with farmers in the Coal River Valley (Chapter 3), participants expressed their curiosity about the reasoning of their neighbours, as they all agreed it is impossible to make a profit with either livestock or traditional annual crops (e.g. cereals) using SE3 water. Instead, farmers have to change enterprise into high value cropping. This is backed by a Cost Benefit Analysis (CBA), provided by TI to potential buyers, indicating that yearly costs of SE3 water are not covered by additional gains in gross margins of irrigating pasture to finish store lambs and cattle, or growing cereals under irrigation (Tasmanian Irrigation, 2012c). However, when cycling or driving through the area one will see both cereals and pasture (for grazing) under irrigation. This leads to the hypothesis that farmers' personal reasoning goes beyond short term (economic) gains in gross margins, as suggested by Raworth (2017). This hypothesis has implications for information provision to farmers to better assist them with their investment decisions in joint irrigation infrastructure. In the water related outcomes of the workshop (section 4.3) we therefore focus on personal reasoning that explains deviation from the decision whether or not to invest predicted by the gross margins model.

WORKSHOP

The design of the workshop is structured using the framework to design and facilitate a participatory crossover analysis workshop proposed in Chapter 3, which contains five steps. In the first step, we check that the workshop's aims are consistent with key aims of participatory crossover analysis, namely eliciting personal reasoning, improving understanding of where differences in preference come from and providing insights for regional planning.

The second step is to analyse the decision making context and determine whether conditions are suitable for a participative crossover analysis workshop. The conditions are: 1) Preferences are subjective, which means there is no objective optimum 2) there are at least two discrete alternatives to compare, 3) there is a dialogue situation, and 4) a capable facilitator. In the SE3 scheme, the first two conditions are assumed to be met because investment decisions were non-uniform in the SE3 pre-feasibility stage. With the opportunity to buy summer rights and winter rights expected to go on sale within two years, there are still relevant alternatives to be discussed. We assessed the dialogue situation during on-farm interviews (see section 2.2.2). In a constructive dialogue situation, participants must be willing to listen, have the ability to provide or explore the explanation for their position and must be open to reflection (Bohm, 2004; Habermas, 1998).

The process of preparing for and organizing the workshop (Step 3 and 4) and the evaluation (Step 5) are presented in the following sections

SELECTION OF PARTICIPANTS

As there was no existing community of practice, we contacted the chairperson of the irrigation committee for contact details of both irrigators and non-irrigators covering as diverse a set of enterprises as possible. This selection procedure resulted in a list of thirteen possible attendees for the workshop, being two perennial (fruit) growers, one lettuce grower, five irrigators that (currently) irrigate grains and pasture, four non-irrigators and one investor. There was a wide range in age and farm size, but just one female farmer. All possible attendees had long term farming experience. The chairperson first contacted the intended attendees to ask for permission before we started the first phone enquiry to explain that the process would entail two events: a farm interview plus a workshop, with the possibility to withdraw at any stage. Twelve of the thirteen possible attendees agreed to be interviewed; only the investor was not interested. The farm interviews were conducted in November-December 2017.

INTERVIEWS

The 1-2 hour interviews consisted of a structured part with descriptive questions about farm and water use to explore the differences between enterprises (Table 4.1), followed by a semi-structured part focusing on personal reasoning when considering investing in irrigation and on future views of valley progression (see Appendix IIIA for interview script). In the second part, the interviewer asked clarification questions, follow-ups and used summarizing to encourage reasoning, as recommended by Dunn (2000). These insights of personal views and reasoning were used to determine the relevant workshop questions and follow-ups. The interviews were also used to introduce the idea of crossover points as WTP. The interview process allowed participants to get to know the facilitator, build a relationship, and make an informed judgement whether the workshop would be worth their time. To avoid interrupting the "flow" of the conversation by note-taking, interviews were recorded.

During the interviews, both irrigators and non-irrigators gave signs of not really being open to the input of others – the quote *"The others just don't have a clue"* is illustrative. Some participants suggested the scheme had divided farmers into an irrigator group and a non-irrigator group, leading to a polarized situation. The conditions for a constructive dialogue did not seem to be met. Instead of not proceeding, we decided to try to create a dialogue situation during the workshop.

WORKSHOP DESIGN

For both the process and content, workshop design is of major importance (Scholz et al., 2014a; Stringer et al., 2006). Location, duration and the number of participants are all design decisions that influence the discussion process (Dialogue Matters, 2018; Ridder et al., 2005). Our 3 hour workshop was held in the Sorell community centre in December 2017 (summer). The initial polarized situation was underpinned by over-heard comments such as *"What is he doing here? He knows nothing about farming"* and *"Luckily he is not invited, he would not have added to the discussion"*. Four irrigators and three non-irrigators attended the workshop. With approval of the participants, the workshop was recorded and transcribed verbatim. In addition, a note taker focused on assessing participant reactions during the workshop process and assisted the facilitator by highlighting when clarification was needed.

The workshop facilitation, tools, and establishment of ground rules also influence the discussion process (Ridder et al., 2005; Scholz et al., 2014a). When opening the workshop, the facilitator paid explicit attention to explaining the conditions for a dialogue, without being directive, by focusing on the opportunity for participants to learn about the personal reasons of others when listening, sharing, and being open to differences. The facilitator explained they would discuss virtual scenarios, in which each participant still had their current knowledge and (irrigation) experience, but with no irrigation infrastructure in place and a "once in a lifetime opportunity" to buy water, as they had during the pre-feasibility stage of SE3.

To display the WTP, we used a PowerPoint add-in for polling called TurningPoint (Turning Technologies, 2019). This includes personal clicker devices that allow answers to remain anonymous.

Four questions - checked for relevance by a non-attending member of the Irrigation Committee and a TI scheme operator – guided the workshop:

1. What is the maximum price per ML that you would be willing to pay for a water right? Why?
2. What is the maximum price you would have been willing to pay for a water right if reliability had been 80% (instead of 95%)? Why?
3. What is the maximum price that you are willing to pay for winter water rights ($/ML)? Why?
4. What is the minimum value/ML you need to generate to make SE3 water worthwhile? Why?

The wording of these questions is consistent with standard practice in WTP analyses (Johnston et al., 2017) as participants are asked to indicate at what specific cost they would change their preference and to compare between multi-attribute alternatives. Participants were asked to fill in their initial WTP by clicking their personal devices and additionally to indicate how confident they were about their WTP on a personal sheet of paper. The facilitator displayed the range of (anonymous) answers and, to start the discussion, asked for or picked a volunteer to explain their reasoning, without necessarily identifying which WTP response was theirs. From this initial personal reasoning, other participants added to the discussion as to why their WTP differed (or not). The facilitator ended the topic by asking the participants to fill in their final WTP via TurningPoint and their confidence level about their WTP, as well as whether (and why) their answer changed, on their personal sheet. This process was repeated for each question. For the workshop script, see Appendix IIIB.

EVALUATION

Directly after the discussion, the note taker facilitated a thirty-minute evaluation to gather preliminary feedback on the workshop: whether participants were comfortable to share their reasoning, whether they believed others in the group were honest during the workshop, and whether they would recommend the workshop to others. A more detailed evaluation in the weeks after the workshop focused on learning related outcomes. By phone, each participant was asked open questions including what they remembered as particularly useful or interesting, if/how the workshop changed the participant's thinking and decision-making, and about the perceived usefulness/value of the discussion to themselves and to others (Appendix IIIC). The evaluation of Chapter 3 suggests participants find it difficult to make explicit "what" they learned and how that influences (future) investment decisions. Therefore, we also evaluated appreciation of the workshop to capture perceived usefulness. Willingness to recommend the workshop and to participate in future workshops are meaningful indicators when evaluating participative processes (Ridder et al., 2005).

4.3. RESULTS

REPORT OF WORKSHOP DISCUSSION

Before starting the discussion, the facilitator displayed the interview findings (Table 4.1). On top of water rights, farmers experience additional costs to start irrigating, such as costs for pumps, pipes, irrigators, farm dams, planting trees and landscaping. Additional costs range from zero to two million AUD per farm. Table 4.1 shows that the valley is in transition as, currently, not all water is used. Most irrigators indicated during the interviews that they are still in the process of understanding what they want to use irrigation for, and expect to increase both their area under irrigation and water use in the future.

Table 4.1. Interview findings about differences in farm characteristics, including water use and additional costs.

	Min	Ave	Max
Total hectares	30	243	600
Hectares under irrigation	0	23	70
Hectares under irrigation future	0	70	200
Years of irrigation experience	0	15	40
SE3 water allocation (ML)	0	65	300
Current water use (ML)	0	47	200
Water use per ha (ML/ha)	0,6	2,1	5
Current value generation ($/ML)	0	3.277	20.000
Pumping costs ($/ML)	0	89	120
Other capital costs to start irrigating	0	348.750	2.000.000

WTP FOR SE3 WATER

The first workshop question elicited the WTP for a right to one ML of water. The first respondent to the question "why?" explained that their WTP goes beyond economic reasoning and instead focusses on qualitative, personal factors (see quote 1 in Box 4.1).

This personal reasoning explains that the Cost Benefit Analysis of TI (Tasmanian Irrigation, 2012c) does not guide the decision rule of this participant. Instead non-monetary factors have more "weight". This comment was followed by other participants agreeing with the last statement, notably expressing a preference for buying land where it rains instead of buying water.

Then one of the irrigators explained that he invested due to the climate and location (quote 2, Box 4.1), but that he could see why it was different for other participants. From here on – relatively soon after posing the first discussion question – participants acknowledged differences between each other. They asked each other questions to clarify, patiently explained, and treated each other with respect – all engaging in a lively dialogue.

The conversation then touched on the difference between actual uptake and what they would have liked to buy, as some participants had temporary budget constraints. Others wished they had used a different bank as they could have borrowed more. None of the irrigators indicated they had too much water. Instead, two of them bought more water on the water market since they started irrigating and others were considering increasing their summer allocation.

Box 4.1. Quotes regarding WTP for water

1. *"You have to look at the infrastructure cost, you have got to look at your age, and you have to look at the quality of life. I went to a lot of meetings and people were not there because they had to move irrigators and were up in the middle of the night. I am more comfortable and have less stress while doing what I am doing."*
2. *"In my case, this is the ideal place. It has the climate to do what I want to do so I am prepared to pay for it. I have a business that needs the water. But I can appreciate their view".*

INFLUENCE OF RELIABILITY AND SUPPLY REGIME (WINTER/SUMMER) ON WTP

When discussing the influences of reliability on their WTP for water, it became clear that not all benefits are tangible and that they may vary over time. A participant explained they use water to "drought proof" the core of their business, leading to less stress (quote 3, Box 4.2). An irrigated part of the business can feed into other parts of the business, reducing weather related risks, allowing for flexibility and robustness to wait for better (market) prices. A lower reliability would influence this drought proofing and therefore the stress reduction impact of owning irrigation water rights. What is perceived as a risk turned out to be personal as other participants explained that they see investing in water as a capital risk – notably through mortgages and employment contracts. This perception of risk, which seemed partly related to reliability, influenced their WTP as is displayed in Figure 4.2. Two participants indicated that they would not pay for water with a reliability of 80%.

When discussing winter water, participants discussed the extra costs related to water storage in the winter and the evaporation losses when only needing the water in the summer. They therefore agreed winter water should be cheaper than summer water, which was reflected in their WTP, which all stayed below $2000/ML. The irrigators also argued they should be given the opportunity to buy winter water rights cheaper than "outsiders" as without their investment in summer water, the scheme would not have been built. They heard TI was considering the same price for winter water as for summer water ($2700/ML) which they perceived as unfair. Both irrigators and (current) non-irrigators seemed to agree that there is a growing demand for water, but that it would take a long time to sell winter water for $2700/ML. One of them indicated it would take at least 20 years, with properties being sold to new owners, before all winter water could be allocated at that price.

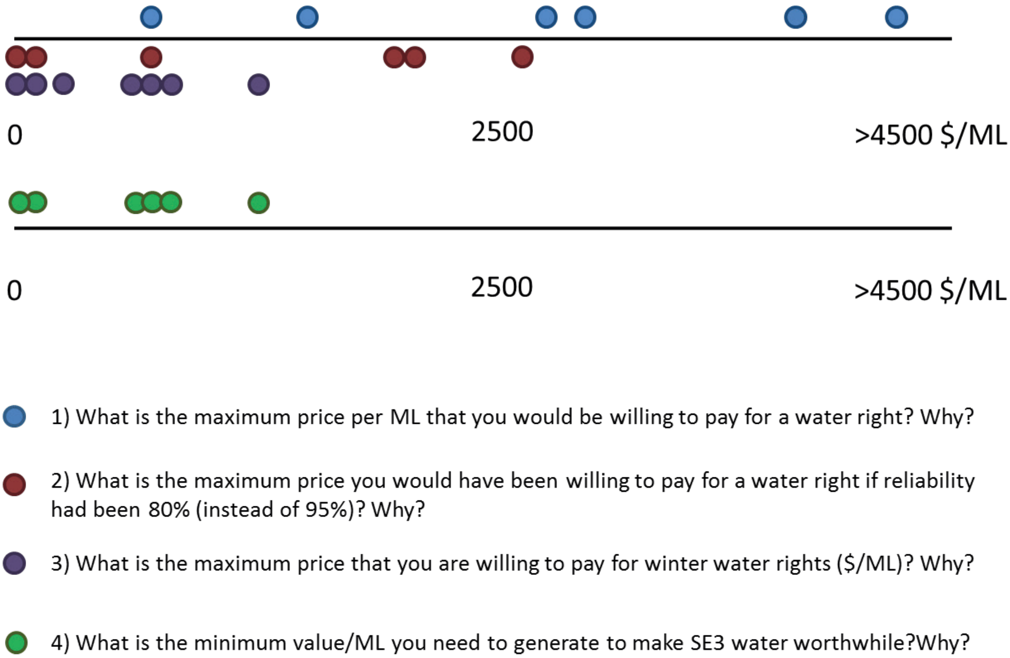

Figure 4.2. Responses to each question after discussion: willingness to pay and minimum value generation.

WHEN IS WATER WORTH IT?

In the discussion about the minimum value/ML one has to generate to make SE3 water worthwhile, the first response focused on a 10% rule of thumb. The participant explained that they look at water as an investment, aiming to make direct profits, instead of focusing on value generation, defined as farm gate value including on-farm value adding (for example grapes into wine) (quote 4, Box 4.2).

This led to a discussion in which others replied that their land purchases did not achieve a 10% return. They saw investing in water rights more like investing in land, slowly increasing in value and therefore not as a cost, but as a good long term capital investment (quote 5, Box 4.2).

In this case, the investment in water might provide the conditions to prepare their enterprise for generations to come. For some participants irrigation seems to be part of their identity - investing in irrigation is not solely based on making profits but instead involves personal intrinsic motivations (quote 6, Box 4.2).

Box 4.2. Quotes illustrating non-monetary factors influencing WTP

3. *"Not F5-ing (refreshing) the weather page anymore"*
4. *"I look at it in a different way. I just look at the profit and I think you have to generate a 10% return on that extra capital. I am not sure how much extra value that generates, but profit is what drives me. That figure is around the 10% mark. You have to make at least $300/ML extra profit, every year, to make it worthwhile".*
5. "*If we did not buy it, the scheme would not have been in. My children might want to go on and grow cherries or other horticulture".*
6. *"I spend a lot on irrigation. Probably don't make a lot of money, but I love doing it. I love seeing the crops. Getting them up and growing. You know, some people might think that I am crazy but it is my thing. I don't go out in a boat or anything else. This is my life".*

EVALUATION RESULTS

The workshop clearly provided a successful venue for farmers to share their personal reasoning and as expected discussion went beyond financial or monetary factors. Survey results (Table 4.2) indicated that all participants felt comfortable participating, and were content with the facilitation.

In their immediate survey response, the majority of participants were also positive about the workshop as a whole, but with some hesitating about whether they would recommend it to others. However, in follow-up interviews, they all said they would recommend the workshop to other irrigator groups, especially during the pre-feasibility stage of building a new irrigation scheme. At the end of the workshop, participants suggested organizing another workshop to share their understanding of the value of water for irrigation with farmers from the Coal River Valley, water managers, and policy makers. This workshop took place in May 2018; results are presented in Chapter 5.

The value of the workshop emerged on reflection rather than immediately. Comments in the workshop and in follow-up interviews indicated that some were disappointed that there were just four questions and felt they could have covered more questions but others pointed out that these four questions kept them entertained for over two hours. One of the participants raised the question “what did we learn tonight?” After the facilitator explained (again) that the workshop aimed at better understanding the differences between participants in their water valuation by focusing on personal reasoning, they seemed to be more satisfied with the outcome.

While, for the most part, the participants could not directly link their learning to specific points in the workshop, they acknowledged the value of the conversation. Participants acknowledged differences within the group as an asset and this might influence future dialogues, future learning, and decision making. In addition, the attitude of participants seemed to have changed, acknowledging the perspectives of others, which is a strong indicator of learning from and with peers (Ridder et al., 2005). Participants explained that they still disagree, but respect each other more (quotes 7-9, Box 4.3).

While positive about the workshop, participants had a mixed view of the added value of the WTP questions, as expected at a proof-of-concept stage. Most participants were not surprised by the preferences expressed by others – though this was still a source of learning for some. This was anticipated, given that WTP was used as a “strawman” – it was the intent of the workshop that the discussion that followed their first “guess” was perceived as more insightful than the WTP itself. Some did find the framing – using WTP – to be useful, suggesting it would be worthwhile for future work to investigate factors affecting perception of utility. Evaluation interviews provide evidence in favor of two key hypotheses.

Firstly, the perceived utility of the method was influenced by its execution. The task of expressing confidence levels in particular was “*a bit confusing*”, “*a bit tedious*”, and “*could have been more straightforward*” (quotes 10-12, Box 4.3). At the same time, there was recognition that this perception might have been different for others (quote 13).

A second hypothesis is that it was difficult for participants to evaluate the value of the method at the time of the survey, especially in terms of impact for group understanding. In the follow-up interviews, participants recognized the need to cater for other participants' needs (quote 14). The fact that WTP plays a deliberately transient role also makes it difficult to reflect on its impact – though participants acknowledged it successfully prompted discussion (quote 12, 15). Such issues would need to be taken into account in a rigorous evaluation of the impact of starting the conversation with WTP.

Box 4.3. Quotes reflecting on the value of the workshop and the focus on reasons underlying WTP

7. *"I have been psychoanalysing the district for years. I know everyone's background. I studied it and I was not surprised about others' preferences. It is really about respecting each other's decision. Is that not funny? I have never confronted others and asked them why they did or did not buy water. But for the first time today, with everyone explaining their personal reasons it makes a lot of sense. It is just the reason "why" that makes me accept everybody's preferences. Before I thought they were so silly, but now it does not seem silly: They have realistic reasons and I respect that now".*
8. *"Everyone has their reasons for what they want or don't want to do and they are welcome for that".*
9. *"Everyone here is so different and you can't go out and judge everyone".*
10. *"The piece of paper with confidence levels was a bit confusing for everyone I think.*
11. *"It could have been more straightforward. It could have been a bit more simplified."*
12. *"I found it a bit tedious writing those things down, whatever we had to write down, the confidence. I found that pretty annoying. But all the verbal stuff was good. I did not mind pressing the button on the screen. I thought that was quite clever. It brought everyone's thoughts in but it did not name any names. It was just a trend of what everyone was thinking."*
13. *"It was easy for some but other people still need to understand it too."*
14. *"It took a long time. I already thought about it myself and had an understanding of the other perspectives and so I personally did not need three hours to discuss it, but others did seem to need that time."*
15. *"I am a little bit sceptical about just taking an arbitrary value and selecting that for the questions we have been through. It certainly has prompted discussion and thinking about the subject. So it has added something."*

Table 4.2. Results from the evaluation immediately after the workshop

Environment					
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I believe others in the group were consistently honest throughout the workshop	0	0	0	2	5
I felt able to talk honestly throughout the session	0	0	0	3	4
I felt comfortable to talk about my preferences	0	0	0	4	3
I felt comfortable to talk about my reasoning for preferences	0	0	0	6	1
The workshop facilitation was appropriate for the content and group	0	0	0	7	0
Workshop					
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I would recommend this workshop to others	0	0	3	4	0
If I talk about the workshop to other people it will mostly be positive	0	0	1	5	0
The outputs of this workshop should be interesting to other audiences	0	0	1	4	0

	Variable	Very slow	A bit slow	About right	A bit rushed/ Too fast
The pace of the workshop was	0	0	1	4	0
		Crossover points (Willingness to pay)			
	I hadn't really ever thought about it	About the same as I expected	Slightly different from what I expected	Very different from what I expected	
On average, other people in the group had preferences that were:	1	5	1	0	
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The crossover approach has added something to the way I will think about water investment decisions	0	1	1	3	0
The crossover process helped to inform my thinking about water investment decisions	1	1	4	1	0
The focus on crossover points is a valuable way to guide group discussion	0	2	2	2	0

Chapter 4

4.4. DISCUSSION

WATER RELATED INSIGHTS, RELEVANT FOR OTHER FARMERS, FUTURE IRRIGATION SCHEME DESIGN AND POLICY MAKERS

As expected, the discussion indicated that the conditions under which it is worthwhile investing in water are influenced by a range of factors. The elicited minimum value generation to make SE3 worthwhile deviates from the notion that irrigation of traditional annual crops (e.g. cereals) or livestock is not "worth it" and challenges the current focus on marginal gains to inform investment decisions of potential irrigators (as in Tasmanian Irrigation (2012c)). What "worth it" means is personal; for some it seems to have a monetary focus while for others it is not solely based on improving profits but involves intrinsic motivations, as also acknowledged by e.g. (Šūmane et al., 2018; Vanclay, 2004). Participants discussed the factors they considered in their decision making and the meaning and value of these factors as reasons behind the differences in WTP between participants. WTP for water may start with dollars but it does not end there, as the price of water does not always reflect the (intangible) impacts within a business structure, for example when drought proofing the core of the business. This is especially the case if the decision is seen as inter-generational – to allow the next generation to keep on farming – the investment decision seems to be less influenced by short-term profits.

In the current scheme design strategy in Tasmania, there is very limited flexibility: when the irrigation pipes are in place, with the pipe diameters supplying the current demand of summer water, the once in a lifetime opportunity has passed and the scheme does not provide any mechanism for further increases in regional water availability during the irrigation season. The insights from this participatory water valuation process provides reasons to allow room for learning by doing as it challenges the current approach of supplying "demand". Based on the experiences and predictions of the participants, demand and WTP is likely to change as beginner irrigators indicated they have to learn what they will do with their water and properties will change owner. During the interviews, participants indicated that they hardly ever talk with other farmers about their reasons to invest (or not). Even during the pre-feasibility stage of the irrigation scheme, when they had to commit to buying water rights, most did not discuss the pros and cons of water with peers. Acknowledgement by policy makers and scheme designers that knowledge and understanding will change in the future leads to a water governance challenge to make non-regret design decisions in irrigation infrastructure, see for example (Lawrence & Haasnoot, 2017). How to co-finance joint irrigation schemes, while acknowledging these changes, provides an interesting avenue for further research on water valuation scenarios.

PROCESS EVALUATION

CONTEXT CONDITIONS

According to prior work on participatory crossover analysis, the conditions of the workshop were flagged as difficult: a polarized context in which there did not seem to be a constructive dialogue situation beforehand. However, the group dynamics quickly changed into a productive, non-judging environment in which participants felt at ease to share and admit to not knowing. In the evaluation, participants indicated they were comfortable talking about their preferences and even about their reasoning for preferences. They felt able to talk honestly and believed others were honest as well. These indications and the change in group dynamics suggest that the conditions for a constructive dialogue were created during the workshop. What caused this change is difficult to point out. We provide a list of options that might (partly) explain the change:

1. The productive environment might have been primed during the introduction to the workshop, or encouraged by the facilitator (Groot, 2002). Literature on facilitation illustrates that a facilitator intentionally and unintentionally influences the process (Deelstra et al., 2003; Groot & Maarleveld, 2000; Susskind & Islam, 2012; Tschirhart et al., 2016). In-depth knowledge of the area (partly gathered through the interviews) and knowing the participants by name helped the facilitator to provide a safe environment for the participants, and to "deepen" the discussion/dialogue by asking relevant follow-up questions.

2. The relationship initiated during the interviews might have created an incentive to cooperate, in addition to existing (power) relations with the chairperson of the SE3 scheme, who initially contacted the participants.

3. Although the participants were not excessively polite, their behavior might also have been influenced by a social code that dictates the need to stay friendly and communicative in a group setting.

4. External factors such as “the right timing” might have influenced the process. The scheme was already in place which might have made it easier for the irrigators to speak freely rather than to try to convince others to buy as well.

EFFECTIVENESS OF METHOD AND FUTURE WORK

Given this is only a proof of concept with one small group, a definitive evaluation of the utility of starting the discussion from WTP is not possible. The immediate survey and follow-up phone interviews did however provide evidence that this workshop approach is worth investigating further. The participants’ indications of increased respect for different views implies that judgement and animosity was potentially reduced by group learning in this form, focused on discussing reasoning and acknowledging subjectivity in the optimum. This group learning may provide a foundation for cooperation and collaboration through greater levels of trust and can help to create a common understanding of the diverse values among peers. Doing so, it benefits individuals’ capacity to make better informed investment decisions in joint infrastructure. There are two paths forward: further applications of the method, and deeper investigation of the mechanisms at play.

This study did suggest opportunities for improvement. Special attention needs to be paid to how individuals in the group prefer to interact, as well as differences in prior experience between individuals. The process of filling in their personal sheet before and after the discussion was perceived as confusing and distracting. The indicated confidence levels either increased or stayed the same, only one participant became less confident about their crossover point on winter water. Explanation of “why” either confidence level or crossover point changed was very limited. As the flow of the discussion is important, we recommend avoiding asking for confidence or attempting before-after tests in future applications, unless the workshop is specifically designed to accommodate them.

In contingent valuation literature, it is widely acknowledged that survey design, including the questions, influences outcomes (Bateman et al., 2002; Carson et al., 2014; Choi et al., 2016; Johnston et al., 2017). In Chapter 3, participants compared alternative water sources. In the workshop described here, the questions related to a binary choice of whether or not to invest in water for irrigation. The first three questions were on the cost side, asking for WTP, and the last question elicited the value one has to generate to make the investment worthwhile. It is an interesting avenue for future research to explore whether/how the angle of the question influences the discussion, in addition to the quantitative responses. Based on our experience, we recommend keeping the questions simple – this then provides the opportunity for participants to explain why the question is too simple.

There are promising opportunities for further work to assess the outcomes of such participatory workshops and how the applied method contributes to those outcomes.

4.5. CONCLUSIONS

This study presents a method to explore and share the reasoning underlying decisions to invest in a group setting. In a context in which conditions were not optimal, participants engaged in a dialogue that focused on discussing elicited individual WTP and the origins of group differences, encouraging participants to think about the conditions in which they would (not) invest in water. Asking "why" then helped facilitate a broader discussion on personal reasoning.

Participants discussed that valuation of water is a personal matter, illustrated by the differences in cost prices per ML under which participants invest in water for irrigation. Farmers' personal reasoning goes beyond short term (economic) gains in gross margins. Their reasoning is diverse and does not seem to align with the idea of maximizing short term profits as e.g. life style choices, long term (intergenerational) planning, perceived risks and intrinsic motivations were discussed as factors influencing personal decision making. We therefore recommend revising the information provision to potential irrigators, as it currently is too strongly focused on marginal benefits, and we suggest considering peer-to-peer workshops, such as the one described here, to enrich the knowledge of potential water buyers. A better understanding of the personal reasoning of others can improve understanding of differences, provide new insights into investment decision making processes, and lead to more respect for the (decisions of) others.

We illustrated that a participatory valuation method can guide a group conversation about the personal reasoning that sits behind WTP for water and provided an example in which participants have the opportunity to listen, share their reasoning, discuss, and learn from and with others. We demonstrated that discussing reasons underlying individual WTP is a promising method to help participants better understand how water is valued, as requested by the UN High Panel on Water (World Bank, 2017), and hence help inform decision making about joint irrigation infrastructure. Further testing in further case studies appears to be worthwhile.

5. THE SOCIAL LEARNING POTENTIAL OF PARTICIPATORY WATER VALUATION WORKSHOPS: A CASE STUDY IN TASMANIA, AUSTRALIA

This chapter is submitted for publication as Nikkels, M. J., Leith, P., Mendham, N. J., & Dewulf, A. (under review). The social learning potential of participatory water valuation workshops: a case study in Tasmania, Australia.

Participatory water valuation workshops are useful for their valuation outcomes, but can they also foster social learning among participants? Social learning involves changes in understanding through social interactions between actors, which go beyond the individual to become situated within wider social units. Participatory water valuation workshops involve dialoguing about knowledge, perspectives, and preferences, which may be conducive to social learning. However, whether and to what extent participatory water valuation workshops foster social learning has not yet been empirically assessed. In this chapter, we assess the social learning potential of a participatory valuation workshop, based on a case study in Tasmania, where farmers, water managers, and policy makers shared their personal perspectives on the past, current and future values of irrigation water. To assess whether and to what extent a single participatory valuation workshop can foster social learning, we analysed drivers – i.e. factors positively influencing social learning – and outcomes – i.e. indications that social learning occurred. Data were collected through an exit survey, in-workshop reflections and semi-structured interviews following three weeks and six months after the actual workshop. The results indicate that the workshop provided the drivers for social learning to occur. In addition, participants indicated to have learned from and with others, and that the workshop provided improved and extended networks. According to the participants, the workshop led to a shared concern about increasing prices for water licences and induced substantive outcomes related to the use, management, and governance of irrigation water. The assessment results suggest that participatory valuation workshops, such as the one analysed here, have potential to facilitate social learning.

5.1. INTRODUCTION

Water management and governance has traditionally been characterized by top down command-and-control decision-making with limited attention to learning and adaptive management (Gleick, 2003; Pahl-Wostl et al., 2007b; Pahl-Wostl et al., 2008a). However, end-users, water managers, and policy makers can benefit from learning from and with each other to obtain their goal(s) (Garrick et al., 2017; Pahl-Wostl, 2017; Rodela, 2012; Savenije et al., 2014). A learning approach means that authorities and other stakeholders use dialogue to share perspectives, knowledge and (reasons for) preferences, laying the foundations for negotiations between stakeholders (Working Group 2.9, 2003). Learning approaches in water management actively acknowledge uncertainty and ambiguity (Chapter 6), that values change over time (Wei et al., 2017) and that society and water systems are intimately linked (Falkenmark, 1979; Srinivasan et al., 2017). One form of learning is social learning, in which the learning process is based on a dialogue and influenced by social processes (Muro & Jeffrey, 2008). However, fostering social learning faces challenges. A better understanding on how to foster and assess social learning processes, arguably could positively influence uptake, funding, and acknowledgement of social learning processes.

Empirical assessments of social learning are scarce (Scholz et al., 2014a). In this chapter, we build on previous empirical assessments, such as McCrum et al. (2009); Raadgever et al. (2012); Schneider et al. (2009); Siddiki et al. (2017); Van Bommel et al. (2009); van der Wal et al. (2014), by focusing on drivers and outcomes of social learning in a participatory workshop setting. Drivers refer to factors that positively influence social learning and outcomes are indicators that social learning occurred. Taken together they provide evidence of the extent to which the participatory workshop led to social learning. The proposition that we examine in this chapter is that a single, well-designed water valuation workshop can foster social learning.

Case studies, such as our participatory water valuation workshop in Tasmania, Australia, can inform the literature through allowing detailed focus on the processes underlying learning (Kenter et al., 2016b). This chapter presents our analysis in four sections. We first briefly review literature on social learning and on participatory water valuation. We then argue that deliberative dialogue is a crucial driver for social learning, and introduce the literature we build on to assess social learning. In Section 5.2, we present a framework for assessing whether and to what extent social learning has occurred, introduce the case study, share workshop design decisions, and outline our methods. We then present our results (Section 5.3) and discuss limitations and further research (Section 5.4), before concluding.

SOCIAL LEARNING

Social learning is a broadly used term, which has shifted from being about individuals learning by observing and imitating within a social environment (Bandura, 1977) to the development of shared meanings and practices, founded in participatory processes (Pahl-Wostl et al., 2007b; Wehn et al., 2018). Such processes are influenced by their institutional, cultural and historical contexts (Lumosi et al., 2019; Van Bommel et al., 2009). Literature about social learning often focusses on natural resource management and thus the learning has a purpose of "learning together to better manage together" (Ridder et al., 2005).

Limited agreement on the definition of social learning (Gerlak et al., 2018; Wehn et al., 2018) has constrained its development and evaluation (Reed et al., 2010; van der Wal et al., 2014). In part, the profusion of perspectives is reflected in the diverse goals ascribed to social learning (Siebenhüner et al., 2016). Some see it as a pathway to developing adaptive capacity (e.g. Lumosi et al., 2019; Tompkins & Adger, 2004), others as a foundation of deliberative democracy (Barraclough, 2013; Dryzek, 2006). It is also seen as a means of developing convergence in mental models, common understanding, and consensus (Scholz et al., 2014a; van der Wal et al., 2014). It can also be a strategy to improve cooperation and conflict resolution among stakeholders (Pahl-Wostl et al., 2008b), for instance, to address wicked problems (Huitema et al., 2010). Reed et al. (2010) usefully delimit the definition of social learning by defining social learning in terms of three key requirements: 1) There must be a change in understanding, 2) this change must be a result of social interaction and 3) learning takes place beyond the direct members participating in the learning process. These requirements provide guidance to assess whether social learning has occurred. However, many challenges in defining the extent and attribution of social learning remain (Gerlak et al., 2018).

The above definition implies that social learning cannot be imposed, but the conditions for it can be influenced by the settings of social interaction (Schneider et al., 2009). Lumosi et al. (2019), argue that facilitating social learning relies on creating a “learning space”. Participatory methods (e.g. facilitated workshops) and tools (approaches used in a workshop) are key means to such spaces and influence interaction between participants.

PARTICIPATORY WATER VALUATION

Valuing water is contentious but increasingly seen as an important strategy towards sustainable management of water resources (Garrick et al., 2017; HLPW, 2018). For example, Hellegers and van Halsema (2019) argue that water valuation outcomes can be used to support decision-making processes. Water valuation with stakeholders provides a means to share insights and incorporate the knowledge and expertise of diverse participants (Hermans et al., 2006a).

With regard to valuation with stakeholders, an individuals’ maximum willingness to pay for irrigation water can be seen as a crossover point. A crossover point is a point of indifference; the threshold where two alternatives are equally preferred. For example, to buy or not to buy water. In a workshop setting, differences in crossover points within the group could provide the starting point for a facilitated and structured dialogue to explore where these differences come from. Crossover points have previously been used as tool to examine the effects of assumptions in cost calculations (Arshad et al., 2014; Griffin, 2006; Guillaume et al., 2016). More recently, crossover points were used in a participatory setting to examine personal reasoning associated with preferences for irrigation water sources and willingness to pay for irrigation water (Chapter 3&4).

Participatory crossover analysis builds on contingent valuation literature by focusing on the processes that underlie responses, as is recommended by Burgess et al. (1998). Such a valuation workshop may not aim at outcomes that directly support (group) decision-making. Instead, using crossover points as a tool in a participatory water valuation workshop acts as a foundation for dialogue-oriented social interaction that may be conducive to social learning to occur. Rather than obtaining a single estimate of value by an individual at a point in time, it provides the participants with an understanding of the factors affecting the variation of values within a group and over time.

DELIBERATIVE DIALOGUE AS A DRIVER IN SOCIAL LEARNING PROCESSES

As indicated above, social learning is based on dialogue (Ridder et al., 2005). A dialogue is defined by David Bohm (2004) to be a "stream of meaning" that flows between participants. William Isaacs (1999) puts it as "the art of thinking together". This "art" or "flow" is a communal effort where participants add, learn, and create something new, ideally without coming to any preliminary conclusions or judgements. A successful group dialogue enables participants to get to know each other, to trust each other, and to establish a relationship of knowledge sharing. However, there are differences in the quality and therefore impact of dialogues as the style of interaction affects outcomes of social learning (Metze, 2010). For example, conversations that do not turn into dialogues between water managers, farmers, and nature conservationists can lead to increased conflict and tension (Aarts, 1998; Lems et al., 2013).

Drawing on work of Habermas, the quality of a dialogue can be referred to with the concept of 'deliberation' in which participants commit themselves to explaining and justifying their positions (Habermas, 1998). The intention of a deliberative dialogue is learning from and with others by sharing and explaining beliefs, values, and preferences (Lo, 2011). Deliberative dialogue is inclusive, open, accountable, reciprocal (Hajer & Versteeg, 2005), and vital for understanding complex issues and perceptions (Dryzek, 2006). Habermas (2008, p.50) outlines four conditions for deliberation in learning processes: 1) Inclusive: no one capable of making a relevant contribution has been excluded. 2) Equal rights to engage: participants have the same opportunity to speak. 3) Exclusion of deceptions and illusion: participants are free to speak their honest opinion and must mean what they say. 4) Absence of coercion: communication is free of restrictions in discourse and procedures. Although there is limited explicit reference to social learning in Habermas' work, social learning scholars specifically highlight Habermas' interpretation of deliberation as a key driver of social learning processes (Dore, 2014; Kenter et al., 2016b; McCrum et al., 2009; Orchard-Webb et al., 2016; Ranger et al., 2016; Reed et al., 2010; Rodela, 2013) and of participatory valuation (Kenter et al., 2016a; Orchard-Webb et al., 2016).

Habermas's critics reject the conditions for deliberation as fictions Flyvbjerg (1998). Power relations in particular can negatively influence the conditions to have a deliberative dialogue and learning (Orchard-Webb et al., 2016; Van Bommel et al., 2009). We take Habermasian conditions as ideals rather than features of real-world action situations. They are things to aim for, to evaluate against, and to help assess whether conditions were created for a deliberative dialogue.

OUTCOMES OF SOCIAL LEARNING

Learning takes place at the individual, group, and system level (Rodela, 2011) and in cognitive, normative and relational domains (Huitema et al., 2010). Outcomes can be tangible or intangible and they can develop over time (Bull et al., 2008) So, outcomes are hard to assess and it can be too early, or too late to evaluate them fully (Forester, 1999). Therefore, Webber and Ison (1995) recommended evaluation both during and after the workshop and warn against selecting a narrow set of indicators to assess outcomes.

To assess social learning, the process – including the drivers for a successful learning opportunity – and outcomes can be evaluated (Kenter et al., 2016a; Siebenhüner et al., 2016). Scholz et al. (2014a) provide an analytical framework to assess outcomes of social learning facilitated by participatory methods. They focus on three domains:

- Relational outcomes, indicated by a creation of trust, and the change in network. A change in networks includes newly established relationships, changing roles within an existing network or the ability to cooperate within a network.
- Shared understanding, indicated by convergence in mental models of actors.
- Substantive outcomes, such as actions and rules.

The latter would imply an effect beyond the actors directly involved, which is a requisite of the social learning definition of Reed et al. (2010). As they only applied their framework in an agent-based model exercise (Scholz et al., 2014b), the authors call for empirical applications that assess the processes underlying, and the outcomes of, social learning.

5.2. METHODOLOGY

The first question of concern when assessing and evaluating a process aimed at social learning is whether learning has occurred, as participating does not necessarily mean learning (Collins & Ison, 2009). To assess social learning, we draw on the framework of Scholz et al. (2014a) to assess whether social learning occurred during a participatory water valuation workshop. Unlike Scholz et al. (2014a), our focus is not on converging mental models or developing understanding of a biophysical or technical system. In our case, the focus is on the personal valuation of water and the reasoning behind it. In a participatory water valuation workshop, a shared understanding may not necessarily mean converged understanding. Participants learn about their own valuation within a group, but also about others' valuation of water. This includes learning from the group about how valuation could be (how it is for others), change the perception of group or group members; or change perceptions of self. In these contextual forms of social learning, divergence of positions can be as meaningful as convergence of understanding. We see diverging valuation as a worthwhile outcome of social learning processes, i.e. still disagree but better understand others and respect them more (see e.g. Barraclough (2013; Chapter 4)). We therefore argue that, at least in our case study, converging perspectives are too narrow a scope to assess social learning.

Despite the difference in focus on the form of learning, the approach of Scholz et al. (2014a) remains useful in examining outcomes in one or more domains – relational outcomes, shared understanding, and substantive outcomes (see Table 5.1). For the drivers that influence outcomes of a process aimed at social learning, we draw on the work of Habermas, and more specifically on Kenter et al. (2016a) and de Vente et al. (2016). Kenter et al. (2016a) provide a theoretical approach for Deliberative Value Formation (DVF) of ecosystem services. Process design – including group composition, location, and participatory tools – and facilitation are their two most important factors of influence in DVF processes. de Vente et al. (2016) come up with seven recommendations for participatory processes designed to foster social learning, including using competent independent facilitation and structured tools that help sharing of personal reasoning. We evaluated personal appreciation of the workshop to capture perceived usefulness. Appreciation of the workshop process, captured by willingness to recommend the workshop and to participate in future workshops is a meaningful indicator to evaluate participative processes (Ridder et al., 2005).

Table 5.1. Drivers and outcomes of processes aimed at social learning, adapted from de Vente et al. (2016); Kenter et al. (2016a); and Scholz et al. (2014a)

Drivers	Indicated by:	**Outcomes**	Indicated by:
Deliberative dialogue	Conditions for "ideal speech situation" Participatory tool(s) contributing to the dialogue Appropriate facilitation	**Relational outcomes**	Creation of trust Change in network
Process design and facilitation	Willingness to recommend to others Willingness to participate in another event	**Shared understanding**	Change in *personal* understanding / thinking / reasoning Change in the perception of the understanding / thinking / reasoning / perspective *of others*
		Substantive outcomes	Ongoing discussion beyond the participants involved Initiation of projects / actions / follow-ups

So, we do not focus on “how” learning took place but instead, we assess 1) the drivers to facilitate an opportunity for social learning to occur and 2) outcomes in one or more

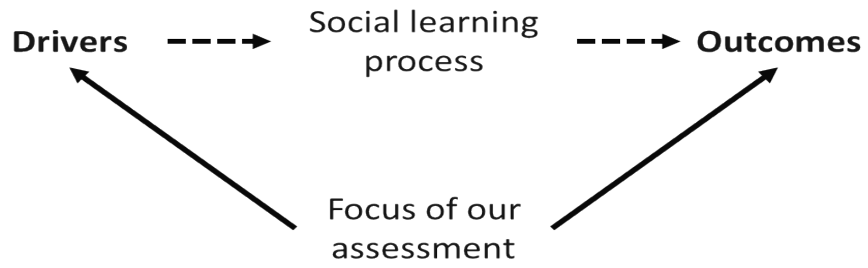

Figure 5.1. Conceptual framework of our approach to indirectly assess social learning by focussing onto assess drivers and outcomes of processes aiming at social learning

domains (Figure 5.1).

CASE STUDY

The South East irrigation district (Figure 5.2) is a prime agricultural area in Tasmania, Australia. There are currently multiple, distinct water sources in the valley, including water from the Craigbourne dam (SE1), treated waste water, and South East Stage 3 (SE3). SE1 provides the oldest and first communal source of irrigation water that farmers invested in (Tasmanian Irrigation, 2019a). Treated waste water currently comes from the nearby municipality (Clarence), but the cities of Hobart and Glenorchy might provide a future extension of this water source (Tasmanian Irrigation, 2019b). Water in the SE3 scheme is sourced from the Derwent River, which has the potential to sustainably provide much more irrigation water than it currently does (Tasmanian Irrigation, 2019c). The SE3 is the newest source of irrigation water in the district and the most expensive water in the State (Tasmanian Irrigation, 2017).

The district is seen as an example for other areas in Tasmania to better understand the societal changes associated with shifting from dryland cropping into irrigation (Nelle, 2010). This is particularly relevant in the Tasmanian setting as there are long term policy objectives to increase the annual value production of the agricultural sector from $1.8 billion in 2012 (Australian Bureau of Statistics, 2013) to $10 billion by 2050 through irrigation and innovation (DPIPWE, 2017). This long-term objective results in government initiatives to build new irrigation schemes to facilitate a transformation from dryland cropping to more intensified forms of agriculture (that need irrigation water).

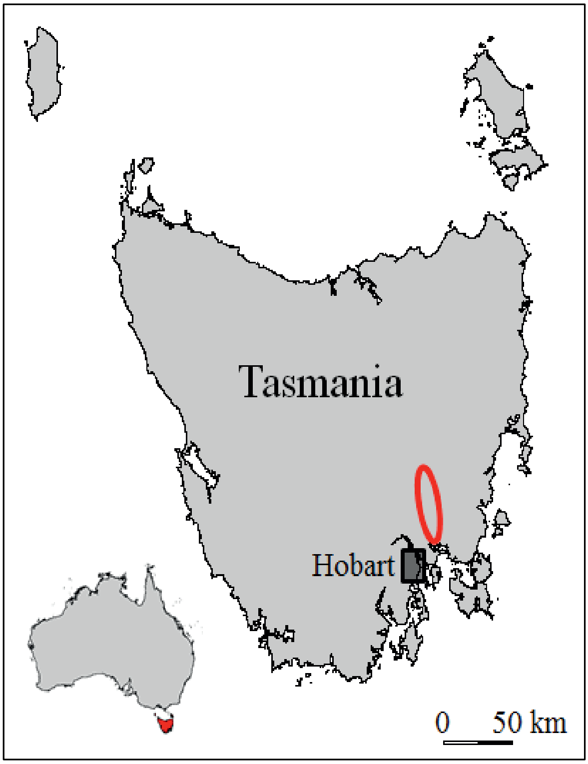

Figure 5.2. Case study area in the red circle

The current approach to design of new irrigation schemes includes a feasibility phase where farmers must commit to buying water entitlements. This first commitment defines the design of the scheme and the diameter (supply capacity) of the irrigation pipes. As such, current water demand of farmers, even if they are inexperienced irrigators, influences the long-term water availability in the district. Information provided to potential irrigators is strongly focussed on marginal benefits, while farmers indicate that their investment decisions go beyond short term profits (Chapter 3&$4).

The demand for water in the district, in terms of both quality and quantity is continuing to increase, and the uptake of SE3 water suggests an increasing willingness to pay for water. As both demand and willingness to pay seem to change over time, the farmers and water managers in the district might have valuable knowledge and experience that may be able to improve the management and governance of water in other parts of Tasmania. However, learning from and with each other is currently lacking in the Tasmanian approach to designing and managing joint irrigation infrastructure, see Chapter 6.

WORKSHOP DESIGN

The workshop was designed to foster dialogue among a heterogeneous group of participants with deep knowledge of water use, management and governance, see Appendix IVA for a step-by-step workshop outline. We took several decisions to enhance conditions for a deliberative dialogue in line with the process drivers outlined above:

- *Recruitment and selection of participants*: We contacted the chairpersons of the SE1, the waste water, and the SE3 irrigator groups. With their permission, we contacted the scheme managers active in the area and the policymakers working on relevant water policies. To include a broader set of perspectives contributing to the dialogue, we encouraged all invited participants to bring a colleague to provide peer support. Four farmers, an irrigation scheme manager, two private sector water consultants with experience in developing and managing irrigation schemes, and one policy maker were able to attend the workshop. Most of them knew each other but the policymaker met most of the other participants for the first time.
- *Creating a safe space*: With the aim to contribute to a setting in which participants felt safe and free to speak, the workshop was held in neutral space within the district.

- *Stated aim of the workshop*: The dialogue among participants was introduced as informal, non-binding, and not seeking consensus. The stated aim was to provide a learning opportunity in which participants could talk about personal perspectives, which might lead to a better and shared understanding, acceptance of these differences, and insights that can result in better water planning and management.
- *Participatory crossover analysis as a tool:* Crossover questions with a monetary focus were used as prompts for dialogue concerning the reasons behind the selection of answers to each question. The workshop sequentially ran through a series of multiple choice crossover questions. Using an audience polling tool (Turning Technologies, 2019) with PowerPoint slides, participants were asked to indicate their personal crossover point to a question (e.g. participants' willingness to pay for water that is provided with 95% surety and of high quality). Anonymised answers were displayed immediately following polling as a frequency distribution and these slides became the starting point; a strawman to encourage personal reasoning. The facilitator (first author) asked for a volunteer to explain why they had chosen their personal crossover point. Further "why" questions followed, opening up inquiry into underlying personal reasoning.
- *Familiarity*: The facilitator knew all the participants personally and had established a relationship during previous workshops in the district. A trusting relationship between scientists (in their role as facilitators) and participants influences both process and outcomes (Lemos et al., 2018; Sol et al., 2013). Due to his research interest in the area, the facilitator was expected to be able to follow and steer the detailed content (see Appendix IVE) and relate to topics covered in previous workshops, see Chapter 3&4.

DATA COLLECTION

To capture emerging outcomes, the evaluation process contained three evaluation moments, spread over six months, see Figure 5.3. A note taker (second author) took notes during the workshop and closed the evening by facilitating a thirty-minute exit survey and discussion to provide preliminary feedback on the process (n=8). Participants answered multiple choice questions, again using TurningPoint audience response software and clickers, and shared their first reflections on the workshop in the group. The questions included whether participants were comfortable to share their reasoning, whether they believed others in the group were honest during the workshop, and whether they would recommend the workshop to others (Appendix IVB). A more detailed follow-up, in the form of semi-structured telephone interviews, three and five weeks after the workshop focussed on the process, and on social learning related outcomes (n=8). These telephone interviews (conducted by the note taker) contained questions focussed on the value of the crossover concept for participants, and the value of the group discussion (See Appendix IVC). Participants were asked what they remembered as particularly useful or interesting, about the perceived usefulness/value of the discussion to themselves and to others, whether they would recommend the workshop and participate in future workshops, and if/how the workshop changed the participant's reasoning/understanding.

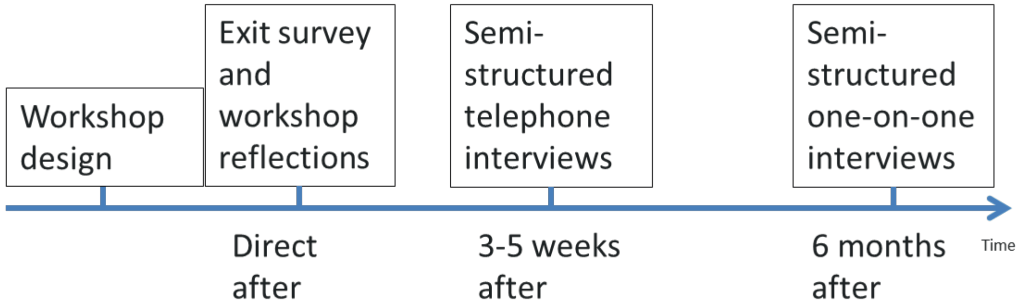

Figure 5.3. Timeline with evaluation moments

To account for any outcomes that might have emerged over a longer time (see e.g. Bull et al. (2008)), the first author interviewed participants six months after the workshop. Semi structured one-on-one interviews contained open questions on the perceived outcomes and whether on not the focus on crossover points contributed to the dialogue and value of the workshop (Appendix IVD). Six out of eight participants could be reached. The workshop itself, as well as the exit survey and both interview rounds were transcribed verbatim and analysed using a deductive coding frame that corresponds with drivers and outcomes and associated indicators in Table 5.1.

5.3. RESULTS

Water-related results of the workshop can be found in Appendix IVE; here we focus on the drivers and outcomes of the social learning process.

DRIVERS

DELIBERATIVE DIALOGUE

Participants' responses at the beginning and end of the workshop, and their answers in both semi-structured interview rounds indicate that we succeeded in providing a deliberative dialogue situation for all participants. Responses to exit survey questions (directly following the workshop) indicated that participants felt safe, able to share their reasoning, and willing to listen to each other. One participant put it as follows: *"I think it was basically that people were prepared to listen to other people. There was no argument. No one said no, that is bullshit. You might have thought it was bullshit, or it does not suit or fit with how I think but that everyone was mature enough, listened, and maybe changed a bit."* Respect for (the reasoning) of others was perceived as a key success factor: all participants agreed that the dialogue was respectful ("*round table dialogue"* as one participant described it). Participants felt comfortable talking honestly and freely about preferences and personal reasoning, and they were confident others were honest during the discussion with reasoning of others being perceived as logical or valid.

Immediately after the workshop, the perceived contribution of the crossover points to the dialogue varied among participants. Most (7 out of 8) agreed that it added "something" but it turned out to be difficult to put a finger on "what it added". The questions were described as ambiguous by some. However, this ambiguity was perceived by others as a key strength of the tool, as it encouraged explaining why the question is ambiguous: What other factors play a role and how do these other factors differ among participants? The anonymous crossover point indications were appreciated as discussion starters, and not as end results. Indicating personal crossover points and then – by asking 'why?' questions – focussing on underlying reasoning helped sharing and explaining perceived values, beliefs, and preferences.

During the workshop reflection, participants seemed to agree that the alternative of a general discussion would have been inferior as it would not have had the depth and explorative character.

During the interviews, all participants indicated that they appreciated the dialogue and appeared to be more positive – compared to immediately after the workshop – about the tool used as it provided a start to the discussion and forced everyone to actively participate. All participants agreed that the tool supported engagement and directed the discourse away from discussing and defending positions: *"There was no right or wrong. It was genuinely participatory and that developed trust and engagement. I thought it worked exceptionally well.*" Another participant expressed it as clever: *"It was cleverly structured to encourage exploring your own viewpoint. Honest discussion of your own viewpoint, which was useful in the end, as it helped to understand why people had different ideas on the same topic."*

PROCESS DESIGN AND FACILITATION

All participants perceived the workshop as being worthwhile. While most (7 out of 8) indicated that the workshop helped to inform how they valued water, participants varied in ability to explain what they learned. For some, the value was in confirming their ideas while for others, the value was in hearing and learning from the different perspectives and getting new information: *"I took away a lot of value out of the workshop by talking to other participants, they also did as well. For different reasons, such as understanding different points of view and opportunities for their business."* During the one-on-one interviews, all participants indicated that they would participate in a similar workshop and that they would recommend others to do so as well. One participant explicitly expressed interest in repeating the workshop every 6 months to continue to learn with and from each other in this particular setting: '*Not so much to set policy or anything but just as lateral thinking sort of group; brainstorming."*

All participants agreed that the facilitation and pace of the workshop was appropriate for the content and group. During the interviews, the established relation during previous workshops was mentioned as a contributing factor: *"I think there is merit in* *making sure that there is a prior relationship and understanding with those in a workshop as detailed as that."*

OUTCOMES

RELATIONAL OUTCOMES

Participants were mixed in their reflections on whether the workshop extended their network. One participant knew all other participants beforehand but the others got to know new people. All indicated in the one-on-one interviews (6 months after the workshop) that it would be easier to collaborate in the future, which was an important outcome and a reason to repeat such processes for the attending policy maker. For some, the improved ability to collaborate had to do with empathy, while others mentioned the bonding effect of having a common understanding: "*The common framework and some common assumptions are there. You don't have to convince those people again*" and "*I think the opportunity to have open and frank discussions with them exist now more so than it did prior. To have the policymaker in the room and understand viewpoints of end-users is just invaluable."*

SHARED UNDERSTANDING

All participants indicated that they either learned about their own valuation or about others' valuation of water. Straight after the workshop, all participants indicated that the workshop informed their thinking about costs and benefits of irrigation water. The following two quotes, captured during the telephone and the one-on-one interviews, illustrate the personal and broad nature of the indicated changes in understanding: *"I think in terms of outcomes that I gained some different perspectives and completely new understanding for water value"* and *"Thinking about other people's perceptions, I thought was really valuable. The farming members of the group were quite alive to the fact that in the long term, water means change. I imagine that this is a very challenging thought for a lot of farmers that see themselves as intergenerational custodians, where their identity is intertwined with their land and what they do. I thought that was very interesting and not explicitly discussed often in relation to the development of these schemes."* Some believed that the learning in the workshop was personal and that others learned more than they learned themselves. This learning did not necessarily mean that their current valuation of water converged but instead, it provided a broader understanding. However, there was a strong consensus about a significant increase in the purchase price of water rights within the next 10 years. Six months after the workshop, this was often mentioned as the most remarkable insight. For example: *"I think, the biggest discussion point that came out is that the perceived value of water has definitely changed in a short space of time."*

SUBSTANTIVE OUTCOMES

The workshop led to substantive outcomes. In the exit survey after the workshop, two participants already indicated that the insights of the workshop would have direct impact on either their farm or their job as a manager/policy maker. During the telephone interviews, the policy maker explained that he perceived the workshop as very valuable from a policy making perspective, as *"It allows policy makers to understand the relevant issues for stakeholders, which can potentially improve policy making".* The policy maker continued exploring the insights he gained during the workshop and started discussion sessions within his department. Six months after the workshop, he had initiated similar social learning processes in other parts of Tasmania and changed the design of new policies towards a more participatory learning approach.

One of the farmers indicated six months later he did not buy more water rights but that the insights of the workshop influenced him in his role in various farmer committees. Instead of looking at the value of water for his own enterprise, he now considers the value of water for other farmers, for example when irrigating high value crops, and incorporated the (possible) future directions of the price of water in his reasoning. Another farmer indicated that it was important to keep on sharing their local knowledge in such settings as understanding the viewpoints of other stakeholders was *"invaluable in the process going forward".*

The water manager and consultants all further explored the workshop topics with their colleagues, challenging their current approach to informing farmers. One of the private water consultants indicated that since the workshop, he was more confident to advise farmers to invest in water, even if the (current) numbers do not stack up: "*It has broadened our advice, I think it helped us to help our clients change the way they think about irrigation development.*" We found that most substantive outcomes, such as changes in the approach to water governance, only became tangible over time, and were evident in interviews six months after the workshop but not earlier.

5.4. DISCUSSION

Social learning processes are often referred to as long lasting, requiring multiple stages (e.g. Johannessen & Hahn, 2013; Ridder et al., 2005; Van Bommel et al., 2009). Some scholars have argued that only intensive, continuous processes lead to learning (Raadgever et al., 2012). Sol et al. (2013) argue that in these long lasting processes, a single workshop can cause significant and enduring shifts, but they still evaluate the overall process. Based on our evaluation six months after, our single workshop seems to have had substantive outcomes, which might start, influence, and steer future water planning and management processes. However, we argue that to assess the social learning potential of short term processes, or in our case a single event, the evaluation process needs to be designed to capture outcomes that emerge over time, which is in line with Bull et al. (2008); McCrum et al. (2009).

Our assessment builds on the work of de Vente et al. (2016) Kenter et al. (2016a); Scholz et al. (2014a) to identify meaningful indicators. We assessed outcomes in three domains, and drivers affecting social learning processes by asking for the perceptions of participants. Doing so, we aimed to capture drivers and outcomes of social learning, as perceived by participants themselves instead of the more traditional approach of directly assessing predefined indicators through pre- and post- measurements of learning, as in Raadgever et al. (2012); van der Wal et al. (2014) or perceptions of researchers/facilitators, see e.g. Sol et al. (2013). Our approach is prone to biases (e.g. hindsight bias, see Kahneman (2011)) and should therefore not be used to assess "how" learning took place. In addition, it is not possible to inventory and separate relevant factors with the rigour required for causal claims as alternative explanations cannot be eliminated (Kampen & Tamas, 2014). However, associations made by participants turned out to be valuable sources of better understanding drivers and outcomes of processes aimed at social learning.

Timing and group composition influenced both process and content of the workshop. Participants indicated that the workshop would have been much harder to facilitate 20 years ago. They all agreed it is of interest for the district, as well as for current and future schemes, to be able to talk about the value(s) of water and to have influence on improved planning, management, and governance. Participants from the local government and nature conservation groups would diversify the group and might provide relevant contributions to the dialogue (inclusivity is one of the conditions for the ideal speech situation, see Habermas (2008)). Siddiki et al. (2017) argue that increasing diversity of stakeholders can have both positive as well as negative influences on learning. Broadening the set of stakeholders provides a fruitful avenue to further explore the applicability of workshops aimed at social learning and is vital if aiming for widespread understanding of complex issues (Dore, 2014).

The role and capacity of a facilitator is widely acknowledged to be crucial to the success of dialogue and deliberative practice (de Vente et al., 2016). In this case, the facilitator's content knowledge and previously established relationship were noted as beneficial to his role in the process. According to Groot and Maarleveld (2000); Groot (2002), the style of facilitation can be defined as "integrative" as the focus is on participants' interests, the reasons behind these interests, values and personal perceptions. An integrative facilitator embraces flexibility and acknowledges multiple perspectives and broad participation. Established rules for a deliberative dialogue (see Appendix IVA) are requisite for an integrative style of facilitation. How the style of facilitation, background, and personality of the facilitator influence the drivers and outcomes of social learning processes deserves further research, see e.g. Siebenhüner et al. (2016).

5.5. CONCLUSION

The evaluation data in our case study suggest that the participatory water valuation workshop succeeded in providing conditions for social learning to occur. Participants indicated that both the facilitator and the applied participatory valuation tool positively influenced the deliberative dialogue among participants. Participants felt safe, listened to each other, respected perspectives, and committed to explaining their reasoning without trying to convince others. The workshop resulted in shared understanding, relational, and substantive outcomes. We therefore conclude that social learning is very likely to have occurred. This is significant, because social learning is often assumed to require long lasting, intensive interactions.

According to the participants, the workshop made it easier to collaborate in the future, partly because they established a shared understanding of the future value of water but also because the workshop created respect and empathy for (the perspectives of) others. This learning did not necessarily mean that their personal valuation of water converged but instead, it provided a broader understanding. Substantive outcomes all relate to new insights: The policy maker related the workshop to changes in his department, farmers changed their view on the value of water for both themselves and others, and water managers feel now more confident to advise farmers to invest in water, even if the current monetary costs and benefits do not stack up.

Participants learned together and continued to discuss and explore the covered topics with others. Six months after the workshop there still was clear enthusiasm to continue social learning. Our evaluation approach provides preliminary insights to promote the uptake, funding, and acknowledgement of social learning processes and so further testing in additional case studies appears to be worthwhile. We found that participatory water valuation workshops are not only useful for their valuation outcomes, but that they can also foster social learning among participants.

6. ADAPTIVE IRRIGATION INFRASTRUCTURE – LINKING INSIGHTS FROM LITERATURE ON HYDRO-SOCIAL INTERACTIONS AND ADAPTIVE PATHWAYS

This chapter is published as Nikkels, M. J., Kumar, S., & Meinke, H. (2019). Adaptive irrigation infrastructure — linking insights from human-water interactions and adaptive pathways. Current Opinion in Environmental Sustainability, 40, 37-42.

Reviewing literature on hydro-social interactions and dynamic adaptive pathways provides insights for the development of adaptive irrigation systems. Irrigation systems face unforeseeable changes in climate, technologies, and societal preferences during their lifetime, potentially rendering them obsolete or inadequate. To remain functional, irrigation systems need to be adaptive to changes as the future unfolds. This chapter builds on the insights from the preceding chapters and proposes a new conceptual approach for developing adaptive irrigation systems by linking insights from the Dynamic Adaptive Policy Pathways (DAPP) approach with the concept of dynamic, coupled human-water interactions. The approach aims to help design and manage irrigation systems in such a way that the investments in infrastructure will not be regretted later. Past approaches to irrigation system design were largely informed by engineering or economic criteria. This is increasingly recognised as insufficient. This chapter provides examples of contemporary irrigation systems in Australia to highlight the need for iterative planning and design approaches that recognise the complex interactions between human and water systems and embrace unknowns. An iterative learning approach to water management allows farmers to influence the water system now and in the future and improves the changes that long term system level objectives will be achieved.

6.1. INTRODUCTION

Irrigation schemes facilitate the intensification of agricultural systems and are usually associated with economic development and nation building (Australian Government, 2015). However, contemporary irrigation schemes no longer command the unequivocal support they once did. Public policy debates now concern trade-offs between the economic potential of irrigation and the prevention of adverse environmental and social impacts. Anti-dam movements in the mid and late 20th century altered public perceptions of infrastructure development and halted the construction of many large dams (Gamble & Hogan, 2019), although recently there appears to be a resurgence (Boelens et al., 2019). Support for existing irrigation systems is also susceptible to shifts in public attitudes. For example, in January 2019, reports of fish kills in Australia's Murray-Darling Basin intensified public debates about water management and irrigation, calling into question the effectiveness of previously negotiated arrangements of water sharing (Australian Academy of Science, 2019). The long-term sustainability of irrigation systems is as much a social and political challenge as it is a challenge for science, engineering, and economics. Past approaches are no longer considered sufficient for the design of new infrastructure (Gleick, 2003). There is a growing body of literature that recognises that water systems are both natural and social and are shaped by the coupled dynamics of human-water interactions (Falkenmark, 1977). In parallel to this literature, there are repeated calls for forward-looking or adaptive decision frameworks to help deal with uncertainty about the future (Garrick et al., 2017; Meinke et al., 2009; Walker et al., 2013). This, combined with invariably contested goals for the future we aspire to, lends significant ambiguity to water infrastructure planning.

Here, we argue that ignoring potential long-term social and environmental consequences of investment decisions can lead to suboptimal outcomes. We use examples from our research in Australia to highlight the need for adopting a long-term perspective when decisions are made about investing in irrigation infrastructure. We explore some of the challenges involved in the development of new irrigation schemes in the Australian island state of Tasmania, at a time when support for existing irrigation schemes in Australia's iconic Murray-Darling Basin is the subject of intense policy debate. How can irrigation systems be designed and managed to be adaptive to a future that will be shaped by largely unforeseeable human-water interactions? To address this question, we review and bring together insights from the literature on coupled human-water interactions and on dynamic adaptive pathways approaches to explore how no-regret decisions could be made about the design and management of irrigation infrastructure.

6.2. CONTEMPORARY IRRIGATION INFRASTRUCTURE DEVELOPMENT IN AUSTRALIA

In 2014, the Tasmanian State Government set a long term goal to achieve an annual agricultural farm gate value of $AUD 10 billion by 2050, which was then almost a tenfold increase of agricultural production value (AgriGrowth Tasmania, 2017). Water is closely linked to this transformation, with irrigation investment proposals using catch phrases such as 'just add water' and 'pipeline to prosperity' (Tasmanian Irrigation, 2012a). The schemes are designed to last for at least 100 years and deliver water at 95% reliability. Reliability is based on modelled projections of water availability through to 2030 under wet, median and dry climate scenarios (Post et al., 2012).

Tasmania takes a deliberate, cautions approach to irrigation infrastructure development. New irrigation schemes have to demonstrate economic benefits, ensure cost-recovery, and meet selected environmental criteria (Australian Government, 2016). The schemes are developed as public-private partnerships, wherein farmers must commit to buying water rights to cover at least 30% of the construction cost of the scheme while the remaining 70% is funded by government. This first commitment defines the design of the scheme and the supply capacity of the irrigation pipes. As such, the long-term water availability delivered through the scheme is determined by the current willingness of farmers to invest. In research carried out by the authors, farmers with no previous experience in irrigation described how their perceptions changed as they learned what they could do with water. Not only their demand for water, but also their willingness to pay for water has increased in the last few years. See Box 6.1 for an illustrative quote.

Box 6.1. Illustrative quote of a Tasmanian irrigator about their changing perspective on the value of irrigation water, from Nikkels et al. (2019b)

> *"I remember when water cost $15 /ML (1000 m3) and it went to $20 /ML and we all thought it was too dear. Sometimes you have got to pinch yourself and realise that I'm about to spend $250,000 just to get access to 50 ML of water. If someone would have told me this 10 years ago, I would have thought he was living in fairyland, but perceptions change. If I tell other growers about the reality of irrigation water they often don't believe me".*

Although irrigation schemes are built with the explicit purpose of transforming the agricultural sector and rural communities, the current design strategy in Tasmania treats social change as outside its scope; it does not explore future scenarios of varying demand for irrigation water or changing attitudes, including the perceived value of irrigation water.

By designing new irrigation schemes based on current demand, (current) economic viability might be ensured, but adaptation to future changes of climate and social values is limited. This can lead to the development of infrastructure that is either inadequate or inappropriate in the future. Nowhere is this more apparent than in Australia's Murray-Darling Basin. Significant investment of public funds in large irrigation infrastructure across the basin spurred private investment and economic development of regional communities for most of the 20th century (Connell, 2011; Musgrave, 2008). Towards the late 1900s however, changing attitudes towards recurrent environmental issues in the Basin altered the political commitment for large-scale infrastructure. Reforms were instituted to buy back water licenses from irrigators and allocate water for environmental purposes, but they remain mired in controversy to this day. Reflection on water resource development in the Murray-Darling Basin leads to two relevant insights:

1) During the life span of irrigation infrastructure, societal preferences and water availability are likely to change;

2) Reallocation of water is a difficult, expensive process that poses a huge political challenge.

These examples highlight the need for greater recognition of the interconnectedness of human-water interactions when irrigation systems are developed.

6.3. RECOGNITION OF COUPLED HUMAN-WATER INTERACTIONS

When water is conceptualised as a resource, biophysical factors such as climatic influences, flow, storage or drainage are often considered independently from human or social factors such as needs, values, or governance (Boelens et al., 2016). Likewise, when water infrastructure systems are planned, social and economic considerations are, to use Lane's (Lane, 2014) words, 'bolted on' to the end of hydrological assessment and design. Many argue that the arbitrary decoupling of bio-physical considerations from social, economic or political considerations has led to adverse consequences for people and the environment (Garrick et al., 2017; Savenije et al., 2014; WWAP (World Water Assessment Programme), 2012). Malin Falkenmark (1977; 1979), an early advocate for interdisciplinary studies of water, pointed out the extent of human influence on water circulation and made the case for a new field of hydrosociology to involve the social sciences in the study of the coupled nature of human-water interactions (Falkenmark, 1979).

Studies of integrated social and environmental systems have proliferated in the last three decades, with notable contributions being made by Elinor Ostrom (1993) on long-enduring irrigation systems and more broadly, the literature on resilience in social-ecological systems. The focus of the social-ecological systems literature is on the system as a whole, wherein interrelationships between components and processes are emphasized (Folke, 2016). However, this literature has met with criticism from many social researchers who contest the application of functionalist ecological theories to the study of human systems, particularly for its inability to account for the role of human agency, power relationships or constructivist theories of knowledge (see Olsson et al. (2015) for a broad critique).

Focussing on studies of human-water interactions, Wesselink et al. (2017) trace and contrast two approaches that have emerged from natural sciences and social sciences perspectives: socio-hydrology and hydrosocial research. Socio-hydrology has emerged as a new discipline that seeks to study the dynamics of society-water interactions to discover regularities that emerge over time in diverse contexts (Pande & Sivapalan, 2017). It aspires to capture all human-nature interactions into a holistic, quantitative model that explains and seeks to predict how human-water systems co-evolve over time (Srinivasan et al., 2017). As with social-ecological systems, the main criticisms of socio-hydrology are its inability to predict human values, human behaviour or social interactions (Di Baldassarre et al., 2016; Melsen et al., 2018) and its inability to deal with knowledge controversies (Lane, 2014). By contrast, hydrosocial research encompasses the work of social scientists and political ecologists who focus on the power relations that lead to inequalities in human-water systems. It sees human-environment interactions as a dialectical process that shapes both water and society. i.e., their relationship is internal. Just as the material flows of water through the landscape influence human activity, social relations – played out through hydraulic infrastructure, laws and policy narratives – determine the flow of water (for example, see (Budds, 2009)). Hydrosocial research is criticised for over-theorizing and not engaging as much with identifying solutions to the problems they articulate (Wesselink et al., 2017).

Regardless of these epistemological differences and limitations, both socio-hydrological and hydrosocial approaches highlight the complex and coupled nature of human-water interactions. Whilst the explanatory power of socio-hydrology is useful in a historical, spatial and comparative sense, the value of hydrosocial research is in its emancipatory power, i.e., its ability to illuminate power asymmetries so that they may be negotiated and addressed. In this regard, the two approaches could complement each other in a pluralistic or reflexive manner (see Lane (2014); Olsson et al. (2015); Sinclair et al. (2017) for ways to do this). While this adds value to the planning and design process, it still does not address the limited ability to support forward-looking decision making. For that, the literature on Dynamic Adaptive Pathways might help.

6.4. EMBRACING THE UNKNOWNS BY EXPLORING ADAPTIVE PATHWAYS

Dealing with future uncertainty is increasingly recognised as a key challenge for the design and management of water infrastructure. (Spiller et al., 2015; Walker et al., 2013; Wise et al., 2014). A promising approach, applied in the long-term Dutch Delta Programme, is the Dynamic Adaptive Policy Pathways (DAPP) approach (Haasnoot et al., 2011; Haasnoot et al., 2013; Haasnoot et al., 2018a; Haasnoot et al., 2018b). The DAPP approach is presented as a new planning paradigm, wherein a strategic, long-term vision is developed based on consensus (Dewulf & Termeer, 2015). Commitments are made for short-term action items while the framework allows for dynamic adaptation over time, i.e., the pathways to reach the strategic vision can be adjusted or switched as the future unfolds (Kwakkel et al., 2016). Predefined tipping points trigger the need to redefine a strategy or to change direction (Haasnoot et al., 2018b). The intention of using the DAPP framework in the Dutch Delta program is to avoid making design decisions now, that will be regretted later (Ministry of Infrastructure and Water Management et al., 2018).

Outside the Netherlands, similar adaptive pathway approaches have been applied in England to develop the Thames Estuary 2100 pathways (Ranger et al., 2013), in New Zealand, where stakeholders explored the influence of climate scenarios in a local flood risk management context (Cradock-Henry et al., 2018; Lawrence & Haasnoot, 2017), and in Australia to develop adaptive plans to adjust to climatic changes in two local coastal regions (Barnett et al., 2014; Siebentritt et al., 2014). In the face of uncertainty, the DAPP approach reduces path-dependencies; it is adaptive to new information; and it allows for greater distribution of costs and benefits across generations (Pande & Sivapalan, 2017).

The main limitations of the DAPP approach relate to its assumptions: that participants have an understanding of (system) complexities (including externalities); that tipping points can be clearly identified; that knowledge is uncontested; and that a clearly defined unambiguous long-term objective can be agreed upon (Bloemen et al., 2018; Bosomworth et al., 2017). Furthermore, we find that applications of DAPP tend to focus on climatic or natural unknowns. The coupled interactions between biophysical and social phenomena are rarely explored. In some cases (for example in Offermans and Valkering (2016)), future changes in climate and societal perspectives are considered together to evaluate the robustness of investment strategies, but these approaches use forecasting techniques, which can be problematic for dealing with unforeseeable changes.

6.5. INSIGHTS FOR DEVELOPING ADAPTIVE IRRIGATION INFRASTRUCTURE

During the lifespan of irrigation infrastructure, unforeseeable changes in climate, the environment, technologies, and societal preference can render the infrastructure inadequate, obsolete or prohibitive to sustain. Hence, we propose a new approach (Figure 6.1) for developing adaptive irrigation systems that brings together insights from DAPP and the literature on coupled human-water interactions. The major difference from DAPP is that the proposed approach recognises the coupled dynamics of human-water interactions by exploring impacts on the water system, society and the environment iteratively. Fig. 6.1 shows this modified, iterative learning and assessment loop, adapted from Haasnoot et al. (2013), that makes this approach applicable for other settings such as coastal or river infrastructure.

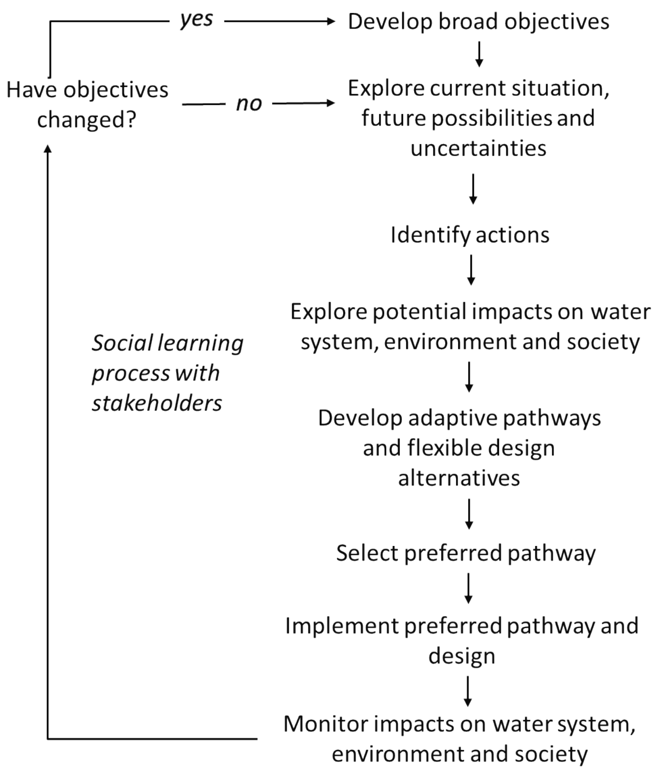

Figure 6.1. Developing irrigation systems in a social learning process by linking hydro-social interactions with adaptive pathways. Adapted from Haasnoot et al. (2013)

Rather than attempting to predict hydro-social changes, we propose that finding the ideal pathway to manage or use water should be approached as an ongoing learning process with stakeholders. The process commences with the development of broad objectives, with the recognition that these objectives will change over time. A prerequisite for such an approach would be a culture that openly embraces and communicates uncertainty and ambiguity[1]. Social unknowns are not to be treated as

[1] Ambiguity is identified as a source of uncertainty (e.g. van Asselt & Rotmans, 2002) or as a dimension of uncertainty (Brugnach et al., 2008). Here, we refer to it separately to stress its significance.

exogenous but instead to be embraced, internalised, explored, and communicated. Uncertainty, ambiguity and ignorance can foster creativity, innovation, and consensus building (Smithson, 1993), but it is important to recognise that they can be used as a political tool (Huber, 2019; Lynch, 2019).

Recognising the importance of the political and institutional contexts of water resource decisions (Boelens et al., 2016; Pot et al., 2018; Ricart et al., 2019), we suggest that as a part of the design and management process, space should be explicitly created for social learning amongst stakeholders. Social learning processes aim to facilitate cooperation among stakeholders based on shared meanings and practices (Wehn et al., 2018) and provide a means to learn together to better manage together (Pahl-Wostl et al., 2007b). Diverse and plural knowledges are a key ingredient to such learning (Zwarteveen & Boelens, 2014). In the Tasmanian research study described above, we found that such processes can also be useful in appreciating social change induced by changes to water systems and vice versa. Facilitated discussions between key stakeholders can create opportunities to appreciate diversity, learn from each other, and enable the identification of potential future pathways. Indeed, community-based social learning approaches to deal with future uncertainty are arguably more justifiable than top-down engineering solutions that regard social values as static and unchangeable (Boelens, 2014; Brugnach et al., 2008; Gunderson & Light, 2007; Jasanoff, 2003). We acknowledge that social learning processes are not immune to issues arising from power asymmetries. It becomes imperative to critically examine the framing of issues and contestations of knowledge to foster conditions for learning.

An important element of the proposed approach is the addition of flexible design alternatives when it comes to irrigation infrastructure development. Irrigation infrastructure is typically expected to last at least several decades, often centuries. Without flexibility in design, the adaptiveness of the overall system is largely constrained. Flexibility is required not only in the design of physical infrastructure (for examples, see (Spiller et al., 2015)) but also in institutional arrangements and management options. We conclude by identifying adaptive design approaches for irrigation infrastructure. This includes suggestions for future research. We provide three examples of strategies that could be explored for the development of adaptive irrigation infrastructure:

1. Improving adaptive capacity through social learning processes that bring together experienced irrigators (or other stakeholders) with farmers who are considering making an investment decision in infrastructure.

2. Organising informal networks and recurring workshops between stakeholders aimed at social learning, ideally decoupled from decision making. Decoupling learning from decision making could help to overcome issues related to power imbalances, allow participants to bridge divides and improve dialogue conditions (Dryzek, 2006; Kanra, 2012).

3. Overcoming path dependency by regulating the water market. Regulation can be done in many ways. One way is for the State to purchase water rights in the development stage with subsequent release of these rights at strategic points in time to regulate the price and allow newcomers to start irrigating. Another way to encourage learning by doing is to lower the upfront cost of water rights and increase the yearly rates. This would potentially lead to a bigger uptake of water rights and farmers pay for the water when they actually have the chance to generate the value needed to cover the costs. An additional option is to stop allocating perpetual water rights, but instead treat water rights as scarce resources such as radio frequencies, that can be bought at auction for a limited period only (say 30 years). This would allow future generations to participate in the scheme and adapt to future social and hydrological changes.

7. SYNTHESIS

7.1. INTRODUCTION

Farmers have always influenced the local and regional water system through on-farm interventions, such as local water storage. They are now being increasingly called upon to contribute to long-term regional water management agendas, for example, by investing in on-farm infrastructure and/or water use licences. At the same time, farmers are themselves influenced by changes in the regional water system, through the coupled dynamics of human-water interactions. Recognizing these coupled dynamics acknowledges that water and society make and remake each other over space and time in an iterative hydro-social cycle.

This research sought approaches and insights to better understand farmers' influence on regional water systems. First, it identified technical and socio-economic challenges in assessing the regional effects of local interventions. Then farmers' reasonings and personal motivations were explored for investing (or not investing) in additional water from joint irrigation schemes. A participatory approach was developed to help farmers elaborate and share their personal and evolving perspectives on irrigation water. That approach was then applied in three workshop settings in Tasmania, Australia. One of the workshops, aimed at fostering social learning, was evaluated based on drivers of success (i.e., factors stimulating social learning) and outcomes (i.e., indications that social learning had occurred).

Each chapter of this thesis addressed one of five research questions:

- What are the main challenges in assessing the regional feasibility of local water storage? (Chapter 2)
- How can crossover points provide insights into farmers' preferences for various water sources (Chapter 3)
- Can participatory crossover analysis lead to a better understanding of personal reasoning behind investment decisions in extra water for irrigation? (Chapter 4)

- Can a single participatory water valuation workshop foster social learning? (Chapter 5)
- How can incorporating human-water interactions in regional water management contribute to achieving long term system level objectives? (Chapter 6)

Figure 7.1 provides a schematic overview of the chapters, their interrelations, and the contributions of each to the overall research objective. The rest of this chapter is organized as follows: Section 7.2 briefly answers the five research questions. Section 7.3 sketches the contributions of the current research to the literature and makes recommendations for future research. Section 7.4 discusses limitations and policy implications of the current work, followed by a summary of the conclusions in section 7.5.

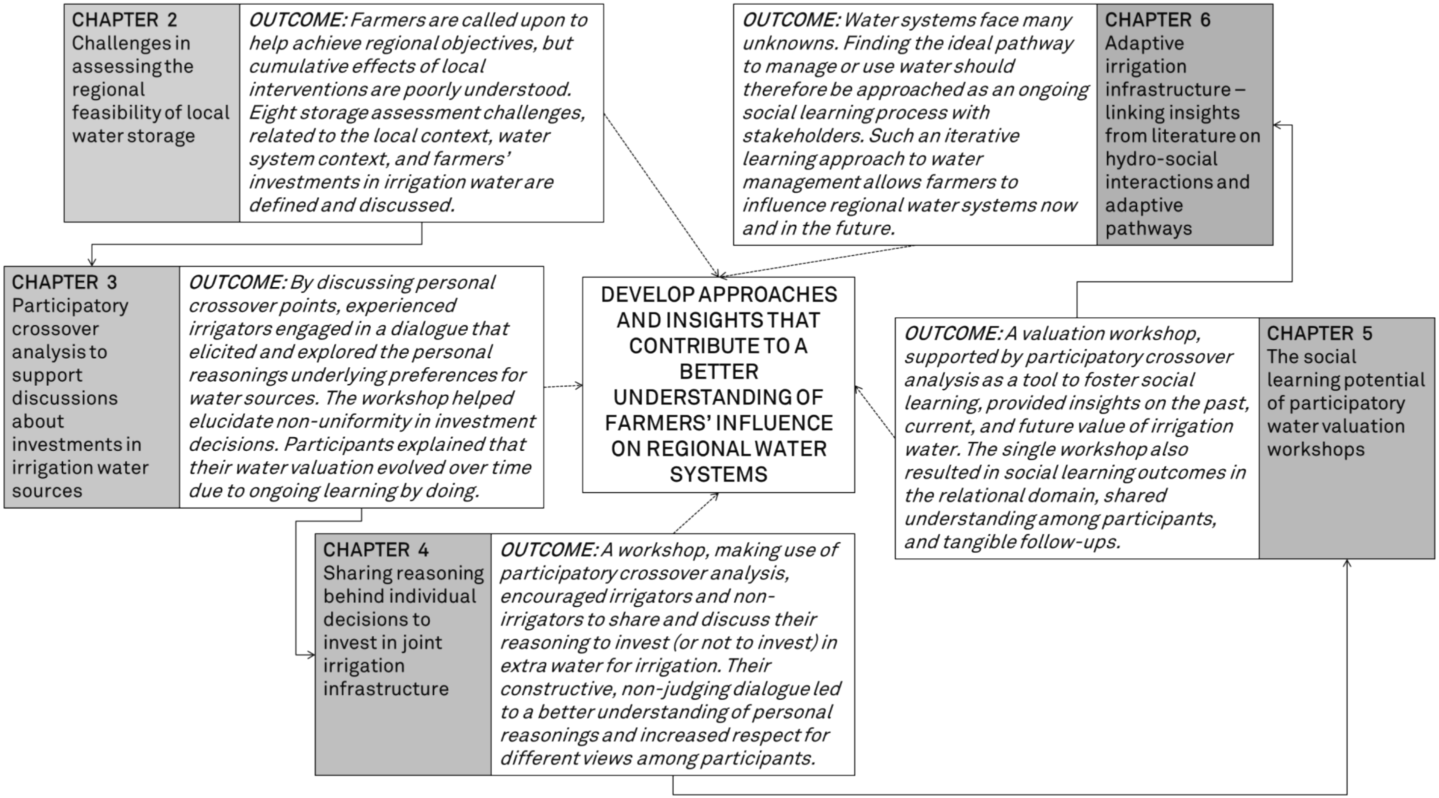

Figure 7.1 Schematic overview of the chapters and their relation to the overall objective. The solid arrows indicate the iterative and inductive approach of the research, with outcomes feeding into subsequent chapters. The dotted lines show that all chapters relate to the overall objective, but from a different angle.

7.2. THE RESEARCH QUESTIONS ANSWERED

Q1. What are the main challenges in assessing the regional feasibility of local water storage?

The system-level implications of local storage interventions have long been poorly understood. This knowledge gap has hampered assessment of regional storage potential. Chapter 2 addressed this knowledge gap by identifying and discussing eight challenges in assessing the regional feasibility of local water storage. The challenges were categorized in three clusters. The first cluster contains challenges related to comparing water storage interventions in their local context:

- Exploitable volumes differ due to differences in manageability and rechargeability
- Stored water may serve additional purposes, such as preventing saltwater intrusion into the plant root zone
- Storage impacts the direct surroundings, influencing the local feasibility of other techniques

The second cluster concerns challenges related to the water system context:

- The spatial and temporal scales of analysis influence assessment findings regarding the overall feasibility of local storage
- Uncertainty about the local availability of water to fill local storage installations reduces reliability
- The actual contribution of local storage to regional objectives is influenced by incorporation of alternative sources, such as return flows, reuse, and regional storage

The third cluster is challenges related to farmer decision-making:

- Costs and benefits of local storage are hard to quantify, especially when benefits pertain to various spatial and temporal scales
- Farmer investment decisions are difficult to predict and may deviate from the economically optimal option

To fully grasp the feasibility of local interventions, we need approaches that help us understand farmers' personal preferences when deciding among alternatives. Specifically, we need to better understand why farmers make the choices they do and the factors that farmers consider when making investment decisions to improve their on-farm water availability.

Q2. How can crossover points provide insights into farmers' preferences for various water sources?

A crossover point represents conditions in which alternatives are equally preferable to a decision maker (here a farmer). By analysing crossover points in a participatory setting, participants provide insights into their personal reasoning underlying decisions on projected water needs and on their non-static, personal preferences among sources.

With this in mind, Chapter 3 explored whether and how farmers' preferences for different water sources could be gainfully discussed and compared in a participatory workshop using crossover points. A participatory framework was developed, applied, and evaluated in an approach termed 'participatory crossover analysis'. The presented step-wise framework advances the crossover literature by serving as a checklist for organization of such a workshop. The framework consists of five general steps: (1) Check whether the aim of the workshop can be satisfied by participatory crossover analysis. (2) Analyse the context and determine whether the conditions are suitable for use of participatory crossover analysis. Proceed to step 3 only if the aims and conditions are clear and suitable. (3) Design the workshop. (4) Facilitate the workshop, and (5) evaluate.

The framework was applied in the Coal River Valley in Tasmania, Australia. In a workshop setting, experienced irrigators shared their knowledge and encountered others' distinct ways of accounting for the factors determining their water source preferences. Three alternative sources of irrigation water were considered, with crossover questions concerning cost, reliability, quality, and manageability. The workshop provided insights on (1) how much and in what way the factors considered would have to change to switch personal preferences; (2) why and how personal crossover points differed within the group; and (3) changes in participants' reasonings over time.

The key insight gained from this workshop was that water source preferences were personal and dynamic. Most participants indicated that their demand for reliable water of high quality, and their willingness to pay (WTP) for water, had increased significantly over the years while they were learning from experience. However, they had very different views on investing in water rights. Farmers valued cost, reliability, quality, and manageability very differently. Particularly, the assumed costs and benefits of the different sources turned out to be personal and subject to change. Deliberately avoiding the assumption of a single 'best' alternative broadened the discussion. Indeed, what farmers perceived as 'best' was far from objective, but turned out to be, at least in part, a personal preference, subject to change over time.

The evaluation revealed that the workshop design and facilitation were effective in creating conditions for dialogue eliciting and exploring farmers' distinct lines of reasoning. This provided a foundation for generating respect for differences in preferences and decision-making. Reflecting on personal reasonings and learning from and with others to understand why crossover points differed turned out to be both relevant and useful to participants. Most indicated that they would be willing to take part in another workshop and would recommend the workshop to others. They also agreed that the content of their discussions would be of interest to others. This suggests that participatory crossover analysis can improve researchers' and policymakers' understanding of farmers' preferences for water sources, by revealing the diversity of reasonings that underpin investment choices. However, actively participating in the workshop was said to provide greater opportunity for learning than merely reading about workshop outcomes.

Q3. Can participatory crossover analysis lead to a better understanding of personal reasoning behind investment decisions in extra water for irrigation?

Chapter 4 implemented the concept of participatory crossover analysis in a water valuation setting, using crossover points as willingness to pay (WTP) scenarios. This built on findings from Chapter 3, in which participants compared alternative water sources. In Chapter 4, the crossover questions related to the binary choice of whether to invest (or not to invest) in high quality, reliable volumes of water for irrigation from a joint irrigation scheme. The questions focused on WTP for high quality, reliable irrigation water. Participants were experienced irrigators and non-irrigators from the valley adjacent to the Coal River Valley. Participatory crossover analysis here centred on the personal reasonings underlying decisions to invest in extra water for irrigation.

The participatory approach to water valuation sought to improve on contingent valuation approaches by focusing on the factors determining investment decisions (as recommended by, e.g., Burgess et al. (1998)). Thus, the intention of the workshop was not to find one 'true' WTP or one 'right answer', as would be the aim of a more positivistic approach to valuation. Using WTP as a starting point for discussions provided an opportunity for participants to explore their own reasonings and compare these with others'. In this way, crossover analysis provided a means to share insights and incorporate the knowledge and expertise of others in a participatory water valuation setting.

Farmers' personal reasonings went beyond short-term economic gains and gross profits. Their considerations were diverse, and did not seem to align with the idea of maximizing short-term profit. Indeed, participants indicated that the monetary costs and benefits of high quality, reliable water were expected to vary over time and that not all benefits were direct and tangible. Intangible benefits included drought-proofing the core of a business and flexibility to wait for better market conditions. Beginner irrigators indicated that they had to learn how to use irrigation water in their enterprises, and expected both their WTP and demand for water to increase with experience.

In addition to monetary costs and benefits, the workshop elicited nonmonetary values, and dug deeper to understand the assumptions and personal logics underlying these. For example, influential factors included lifestyle choices, long-term (intergenerational) planning, managing (perceived) risks, and intrinsic motivations. These insights, elicited through the participatory approach to water valuation, explain why an individual farmer might consider an investment in additional volumes of high quality, reliable water for irrigation 'worth it'. Whether an investment in water is 'worth it' turned out to be a personal value judgment subject to change.

The evaluation data suggest that the workshop provided new insights on the investment decision-making processes across participants. Despite rather negative dynamics at the start of the workshop, group dynamics quickly changed to a productive, non-judgemental environment in which participants felt comfortable enough to share and admit to not knowing. The focus on personal reasonings improved participants' understanding of differences among themselves in water valuation. The workshop generated more respect for others and the decisions they made. All participants indicated that they would recommend the workshop to other irrigator groups, especially during the pre-feasibility stage of new irrigation schemes, to enrich the knowledge of potential water-buyers.

Q4. Can a single participatory water valuation workshop foster social learning?

Chapter 5 assessed the social learning potential of a single participatory water valuation workshop. This contributes to the social learning literature, as most of this literature indicates that lengthy, intensive processes are required for effective social learning. Farmers, water managers, and policymakers shared their personal perspectives on the past, current, and future value of irrigation water in south-east Tasmania. In a workshop setting, an analysis of differences in personal water valuations, expressed in crossover points, provided the starting point for a facilitated and structured dialogue exploring these differences. Participatory crossover analysis was found in this case to stimulate the sharing of personal knowledge, perspectives, and preferences, which is conducive to social learning. Pahl-Wostl et al. (2008a), among many others, argued that social learning improves capacities for sustainable water management.

To assess whether and to what extent a single workshop can foster social learning, drivers (i.e., factors stimulating social learning) and outcomes (i.e., indications that social learning occurred) were analysed. This was instead of focusing on 'how' learning took place. The assessment results suggest that the workshop did provide drivers for social learning to occur. In addition, participants stated that the workshop improved and extended their networks; fostered shared concern about increasing water licence prices; and induced changes in the use, management, and governance of water for irrigation.

These results suggest that participatory valuation workshops, such as the one analysed here, have strong potential to facilitate social learning. All participants indicated that by informally sharing information, they learned from and with each other. Pahl-Wostl (2017) considered such informal sharing and integration of knowledge essential for improving regional water management and governance. According to the participants, the workshop made future collaboration easier, partly because participants established a shared understanding of the future value of water, but also because the workshop cultivated respect and empathy for the perspectives and reasoning of others. Hence, participatory water valuation workshops would seem useful not only for valuation outcomes, but also for fostering social learning among participants.

Q5. How can incorporating human-water interactions in regional water management contribute to achieving long-term system-level objectives?

Chapter 6 built on the insights from the preceding chapters. It proposed a new conceptual approach for developing adaptive irrigation systems by linking insights from the Dynamic Adaptive Policy Pathways (DAPP) approach with the concept of dynamic, coupled human-water interactions. By linking the explorative power of the DAPP approach with the notion that water and society make and remake each other over space and time, the aim of the approach was to design and manage irrigation systems in such a way that investments in infrastructure will not be regretted later.

In Tasmania, new irrigation schemes are being developed to facilitate intensification and transformation of agriculture. The new irrigation schemes are public-private partnerships in which farmers are asked to co-invest with other farmers and government to cover construction costs. The current willingness of farmers to invest defined the schemes' design and the supply capacity of the irrigation pipes. However, participants in all of the workshops (described in chapters 3, 4, and 5) indicated that when new irrigation schemes were in place, people began to learn, adapt, and adjust.

Often, they established new enterprises and, consequently, both water demand and farmers' willingness to pay (WTP) increased significantly. This suggests that designing new irrigation schemes based on current demand may ensure economic viability today, but limits potential adaptation to future climatic and societal changes. This can lead to unintentional 'lock-ins' with infrastructure proving unfit-for-purpose in the future.

Together, the insights from chapters 3, 4, and 5 imply that social changes induced by changes in the water system, should no longer be treated as exogenous but instead should be internalized in the design and management of irrigation systems. Incorporating human-water interactions in the management of regional water systems, by anticipating future social and hydrological changes, increases the chance that irrigation schemes will remain fit-for-purpose.

Figure 6.1 presents a modified version of the DAPP approach. Here, the coupled dynamics of human-water interactions are recognized by iteratively assessing impacts on the water system, society, and the environment. The proposed iterative process begins with the development of broad and shared objectives and recognition that even these objectives might change over time. Socio-economic conditions evolve and policy settings change. To achieve long-term system-level objectives, flexibility is required, not only in the design of physical infrastructure, but also in institutional arrangements and management options. An ongoing, iterative learning approach to water management allows both current and future farmers to influence their water system, now and in the future.

7.3. SCIENTIFIC CONTRIBUTIONS AND RESEARCH RECOMMENDATIONS

The main scientific contributions of this thesis are three:

1. *Specification of the main challenges in assessing the regional feasibility of local water storage*. This thesis identified and discussed eight challenges describing why it is so difficult to compare interventions, to assess interventions' cumulative impacts, and to capture farmers' decision-making in models.

2. *Extension of the use of crossover points to a participatory setting.* This thesis presented, applied, and evaluated a new framework that uses crossover points to

support group dialogue on personal preferences for water sources (Chapter 3), as a tool for valuation of irrigation water (Chapter 4), and to foster social learning (Chapter 5).

3. *Presentation of an adaptive approach to irrigation infrastructure, linking insights from the literature on human-water interactions and adaptive pathways.* The research in Tasmania highlighted the power of the rollout of new irrigation infrastructure to trigger social change. It is imperative to acknowledge, explore, and embed these societal changes in the design and management of irrigation infrastructure.

Below, I elaborate on these contributions in more detail, including avenues for future research.

MAIN CHALLENGES IN ASSESSING THE REGIONAL FEASIBILITY OF LOCAL WATER STORAGE

The challenges identified and discussed in Chapter 2 respond to the call by van der Zaag and Gupta (2008) for more research on the regional implications of local water storage. The main challenges in assessing the regional feasibility of local water storage, as identified and categorized here, constitute a first step towards improving storage assessment tools and processes (see Table 2.3). My specification of the main challenges can serve as a guide for future research on assessment of the regional feasibility of local water storage in various settings and from different disciplinary and interdisciplinary perspectives.

The eight challenges identified aim to raise awareness and function as warnings for those undertaking an analysis of local storage techniques. Indeed, approaches to assess farmers' influence on the regional water system must go beyond local or regional hydrology, as the cumulative impact of interventions depends on the various investment decisions made by individuals. What is technically possible or feasible from a system-level perspective may not prove possible or feasible for every farmer individually. This insight motivated to search for ways to improve understanding of farmers' personal preferences and the factors that influence their decisions to invest (or not to invest) in irrigation water.

RESEARCH RECOMMENDATIONS

For further research, I recommend examination of other contexts to explore the generalizability of the eight challenges. In many countries, local storage may constitute the principal – or even the only – means of increasing the amount of water available during the growing season. This may result in a different role of local storage than in the Dutch case. In mountainous regions, for instance, influences on peak flows need to be taken into account (Thomas et al., 2011). For example, farmers might strategically release water from their dams when downstream cities face severe hydrological drought, as happened during the 2018 drought in Cape Town, South Africa (Walton, 2018). In Tasmania, farmers' ability to strategically release water from on-farm storage to support adaptive water management on a regional scale has been explored for the purpose of river health (Cleary et al., 2018; Ellison et al., 2019). Other purposes of local water storage, beyond irrigation, such as to provide ecosystem services, might be worth considering when comparing storage techniques (Mul & Gao, 2016).

Chapter 6 discussed the possibility that climate, technologies, and societal preferences, as well as on-farm and system-level objectives, may change over time. An intervention that supports farmer or system-level objectives at one point in time may thus turn out to be insufficient or undesirable later. For example, in January 2019, reports of fish kills in Australia's Murray-Darling Basin intensified public debate about water management and irrigation (Australian Academy of Science, 2019). In October 2019, satellite images revealed that farmers had full dams, while rivers were dry (ABC News, 2019a), unleashing another public debate on the social desirability of previously negotiated arrangements (ABC News, 2019b). These examples indicate that rearranging or reversing previous changes is a sensitive, political, and expensive undertaking, hampered by lock-ins and path dependencies, described from an environmental water management perspective by Kumar (2016). The implications of the temporal component of feasibility are an interesting avenue for further exploration.

Challenges in assessing how local actors can help achieve system-level objectives are not water-specific. These challenges also pertain, for instance, to the energy sector.

Optimal deployment of centralized and decentralized energy resources at the system level is a key undertaking in multi-energy systems (MES) and features prominently in concepts such as the 'smart grid' (Mancarella, 2014). The challenges can be technical, as storage and transport of energy is of key importance in decentralized systems. However, they can also be social, as regional (energy) objectives increasingly depend on investment decisions, consumption, and behaviour of local actors such as householders (Smale et al., 2017). Similar to managing regional water systems, MES also face uncertainty and ambiguity. The long-term sustainability of MES is as much a social and political challenge as it is a challenge for science, engineering, and economics. Gleick (2003) argued that past approaches for the design of new irrigation infrastructure are no longer sufficient. This statement also seems to apply to MES. These similarities provide interesting avenues for comparative research between regional water management and MES.

EXTENDING THE USE OF CROSSOVER POINTS TO A PARTICIPATORY SETTING

In my research, I developed, applied, and evaluated participatory crossover analysis in multiple settings, aimed at achieving different outcomes. This indicates the approach's broad applicability. In participatory crossover analysis, personal crossover point indications need not be certain or 'right'. No agreement is required on the factors involved, and what is 'best' remains subjective and personal. Workshop discussions, sparked by elicited personal crossover points, cover the set of factors under consideration, as well as how participants understand the factors and integrate them into their own reasoning, the value they attach to each factor, and how values may change over time. The aim of the workshops is to give participants space to explain and explore why their personal preferences may be different from others' within the group. This shifts the crossover exercise away from problem-solving (see, e.g., Arshad et al. (2014); Frey and Patil (2002)) towards a learning mode, with uncertainties, personal reasonings, and assumptions at the forefront of the dialogue. Doing so builds specifically on Guillaume et al. (2016), in which crossover points were embedded in an explorative learning context.

In addition to the aims defined in Chapter 3 (see Table 3.2), this thesis found that participatory crossover analysis could be a valuable tool for understanding the value of irrigation water and for fostering social learning.

WATER VALUATION

Water valuation has recently gained policy interest. Sustainable Development Goal (SDG) 6 relates to water, and SDG target 6.5 pertains to integrated water resources management (IWRM) (UN Water, 2018). A basic principle of IWRM is that water has values, including an economic value, and that these values must be considered in water management (ICWE, 1992; Savenije & Van der Zaag, 2002). Hellegers and van Halsema (2019) suggested that water valuation might serve as a structured and transparent mechanism to improve group decision-making processes.

The participatory valuation exercises presented in this thesis did not aim to contribute directly to group decision-making. Further, the workshops described did not seek the best or optimal outcome, or a definition of a just price. Rather, by enabling a dialogue on personal water valuations, this research responded to the call of the UN High Panel on Water (2017) for water valuation methods that incorporate the personal and multidimensional values of water. The focus on personal reasonings underlying water valuation is also in line with the growing recognition that nonmonetary aspects need to be considered in water valuation, and that greater participation by stakeholders improves consideration of these aspects (Garrick et al., 2017; Graversgaard et al., 2017; Harou et al., 2009). The valuation workshops were designed to facilitate a deliberative dialogue and foster social learning and therefore contributed to broaden the purpose of water valuation, from supporting joint decisions to fostering social learning.

SOCIAL LEARNING

The findings from Chapter 5 imply that a single workshop can foster social learning. This is a distinct departure from most literature on social learning, which suggests that social learning processes need to be long-lasting and intensive (Johannessen & Hahn, 2013; Raadgever et al., 2012; Van Bommel et al., 2009). The assessment approach to social learning presented in Chapter 5 does not focus on ‘how’ learning took place, but instead on drivers (factors contributing to social learning) and outcomes in one or more domains. Improved assessment of the outcomes of processes aimed at social learning might positively influence uptake, funding, and acknowledgement of social learning processes.

For the assessment of drivers, I followed the recommendations of Kenter et al. (2016a) and de Vente et al. (2016) for designing participatory processes that foster social learning. They argued that participatory tools and facilitation are the most important drivers to enable social learning to occur. In addition, assessments link social learning to deliberation; that is, a deliberative dialogue in which participants commit themselves to explain and justify their positions has been found to be a key driver for social learning (see e.g. Hajer & Versteeg, 2005). My research decoupled social learning from actual decision-making. Decoupling learning from decision-making helped move the discourse away from strategic calculative reasoning (see, e.g., Barraclough (2013); Dryzek (2006). Not having to make a joint decision proved conducive to social learning, as it steered dialogue conditions towards the ideal setting for deliberation described by Habermas (1998).

To assess outcomes, I built on Scholz et al. (2014a), who provided an analytical framework to assess outcomes of social learning facilitated by participatory methods. They defined three domains: relational outcomes, shared understanding (captured by converging mental models), and substantive outcomes. I used these three domains to empirically assess outcomes of social learning as perceived by participants themselves. According to the participants, the single workshop produced outcomes in all three domains.

RESEARCH RECOMMENDATIONS

Applications in different settings, for instance, in other countries or in domains other than regional water management, may provide additional insights on the applicability of the participatory crossover analysis framework. For instance, I facilitated crossover discussions in various explorative workshops in the province of Zeeland, the Netherlands, to guide interaction between water managers and farmers who had not collaborated before. In addition, I applied participatory crossover analysis in the Waterhouderij, an initiative in which farmers and water managers actively learned to better manage their own regional water system together (Nikkels et al. (2019e). Despite years of learning together, this workshop revealed that farmers' willingness to pay for water still differed significantly.

There may well be cases in which there is an objective best option, for example, an alternative that provides the greatest net benefit. In that context a more structured approach to participatory crossover analysis might be appropriate (see, e.g., Arshad et al. (2014). By making use of an interactive interface that visualizes the consequences of assumptions on costs and benefits and the ranking of alternatives, crossover points can be used in these cases too to explore unknowns in a workshop setting with stakeholders (see Guillaume et al. (2016). Comparisons of alternatives might be facilitated by 'vulnerability analysis', in which factors that influence the alternatives providing the greatest net benefits are defined and discussed.

Further examination is also warranted of factors that contribute to success in turning around an initially polarized workshop setting, such as we encountered in the workshop of irrigators and non-irrigators (Chapter 4). The reasons why farmers, water managers, and policymakers may initially hesitate to participate in a joint workshop (Chapter 5) should also be further explored. What factors and conditions are at work in stimulating a deliberative dialogue? Useful guidance may be provided by Habermas (2008) on speech, Bohm (2004) on dialogue, and Scharmer (2007) on levels of listening.

In future research, I recommend comparing the presented assessment approach (Chapter 5) with strategies used in other sectors. For example, impact assessment frameworks are commonly used in the development aid sector (Leeuw & Vaessen, 2009). While substantive outcomes, such as schools, wells, and hospitals, are relatively easy to assess, impacts of development projects aimed at social change are more difficult to assess. Impact assessment approaches from the aid programmes seeking to activate social change may provide ways forward in assessment of social learning in the water domain.

PRESENTING AN ADAPTIVE APPROACH TO IRRIGATION INFRASTRUCTURE, LINKING INSIGHTS FROM THE LITERATURE ON HUMAN-WATER INTERACTIONS AND ADAPTIVE PATHWAYS

This thesis proposes a conceptual approach (Figure 6.1) that links insights from the literature on human-water interactions and adaptive pathways. Changes in the water system affect farmers, as farmers and water are interlinked (Boelens et al., 2016; Lane, 2014). Irrigation systems are shaped by the coupled dynamics of human-water interactions (Falkenmark, 1977; McMillan et al., 2016). Facilitated dialogue between key stakeholders in water management can create opportunities to appreciate diversity, to learn from each other, and to enable identification of pathways to potential futures. An ongoing, iterative learning approach improves the ability to adapt to unforeseeable changes in climate, technologies, and societal preferences. Being adaptive to future changes ensures that future farmers will be able to participate and influence the water system as well.

The Dynamic Adaptive Policy Pathways (DAPP) approach was developed to help planning and design of flood protection under uncertain conditions (Haasnoot et al., 2018b). The approach aims to minimize constraints of path-dependence. It allows users to include new information in ongoing processes, and greater distribution of costs and benefits across generations (Haasnoot et al., 2013). However, the DAPP approach has some limitations, including its assumptions (1) that participants adequately understand system complexities (including externalities); (2) that tipping points can be clearly identified; (3) that knowledge is uncontested; and (4) that a clearly defined, long-term objective can be agreed upon (see, e.g., Bloemen et al. (2018); Bosomworth et al. (2017); Pot et al. (2018).

The literature on coupled human-water interactions highlights the close connection between hydrological and social change, but incorporating this understanding in the design and management of irrigation systems is not straightforward (Di Baldassarre et al., 2016; Lane, 2014; Melsen et al., 2018). Therefore, applications of the concept of human-water interactions have been limited by the inability to support forward-looking decision-making (Wesselink et al., 2017). According to Srinivasan et al. (2017), a hydro-social lens can help when looking back, but its predictive power is greatly inhibited by actors' inability to address built-in assumptions and predict human values, human behaviour, and social interactions. Rather than attempting to predict hydro-social change into the future, an adaptive approach to irrigation infrastructure was proposed here. The implication is that design and management of human-water systems should be approached as an ongoing, iterative social learning process with stakeholders.

RESEARCH RECOMMENDATIONS

The conceptual approach presented in Chapter 6 is intentionally formulated in general terms to allow its application to be modified to various settings and situations. I recommend applying the adaptive approach to irrigation infrastructure in a case study setting in which political and institutional contexts influence design and management (Boelens et al., 2016; Pot et al., 2018; Ricart et al., 2019).

I also recommend exploring adaptive approaches outside the field of irrigation, as other sectors seem to offer valuable lessons. For example, in the literature on flexible design of urban water systems, Spiller et al. (2015) and others have suggested that adaptive, phased design approaches may be most suitable for systems that experience change by slow variables such as climate change, societal preferences, and technological developments. Additionally, approaches adopted in highly dynamic domains, such as circular agriculture, telecommunications, IT, and media could be explored to improve adaptive irrigation system design and management.

7.4. LIMITATIONS AND POLICY IMPLICATIONS

LIMITATIONS

The topic of this thesis is broad. Many other research questions could have been addressed and other approaches taken. This section discusses three main limitations of the chosen research emphasis and approaches.

First, one obvious limitation, related to the case study approach, is the difficulty of meaningfully extrapolating context-specific findings to other settings (Kampen & Tamas, 2014). However, case studies such as those presented in this thesis, can inform the literature by illuminating the processes that underlie outcomes (Kenter et al., 2016b) and by providing rich and detailed information on perceptions. For example, the crossover points found in my case studies cannot be taken as stand-alone facts or an objective willingness to pay. They are context-dependent, clearly subject to change, and by no means representative. Displaying crossover points merely demonstrates the differences in perspectives within a group. The primary intent of eliciting crossover points is to start discussion. Given the confinement of the present research to small groups in a single case study area, it is too early to definitively evaluate the utility of participatory crossover analysis, either as representing conditions in which alternatives are equally acceptable to decision makers, or as scenarios for starting a discussion on investment decisions, or as a tool to foster social learning.

The second limitation relates to the difficulty of assessing the outcomes of processes aimed at social learning (Cundill & Rodela, 2012; Reed et al., 2010). Forester (1999) concluded that outcomes are personal, largely unpredictable, and unanticipated. If the scope of assessment is too narrow, thus missing relevant or emerging outcomes, it might actually lead to a lower appreciation of social learning processes. Similarly, predefined indicators, assessed by an evaluator, may underestimate the actual social learning that occurred. The indirect assessment approach presented in Chapter 5 provides an alternative. It allowed participants themselves to reflect on their personal learning and on the perceived learning of others. Nonetheless, such participant reflections are prone to biases, including hindsight bias (see Kahneman (2011). The approach cannot be used to assess 'how' social learning took place, as it is impossible to distinguish and measure relevant factors with the rigour required for causal claims. Based on the modest experience gained so far, assessing social learning by capturing the perceptions of participants seems to be a promising approach, but its benefits and limitations need to be further explored.

The third limitation relates to the stand-alone nature of this research. It was not part of a larger project, nor was it directly linked to ongoing planning processes. This influenced its impact. Integrating research with ongoing planning processes is instrumental if the aim is to impact water management (Reed et al., 2014) or contribute to problem-solving (Siebenhüner et al., 2016). I made a concerted effort to establish lasting connections with key stakeholders. For example, I provided the participants feedback in the form of actionable recommendations, as encouraged by Reed et al. (2014). In addition, I gave radio interviews, organized informal seminars, had many coffee breaks and bike rides with workshop participants, produced a podcast, and gave talks at farmer meetings. However, the impacts of these efforts, both direct and indirect, remain outside the current research scope.

POLICY IMPLICATIONS

The most important, broadly applicable implication for policymakers is that farmers have valid personal reasons to act in a certain way. Farmers are increasingly called upon to co-invest with government agencies to improve the water system. Therefore, they need information to help them decide whether investment in an intervention is 'worth it'. Then, important questions are 'what information is relevant to farmers' and 'from whom should they get it'. Providing relevant information is challenging, as there is no single best way to inform all farmers. Too often, the focus is on transferring quantitative information (what can be counted) from scientists and policymakers to farmers (see also Vanclay (2004). Yet, information also needs to focus on 'what counts'. The findings in this thesis have particularly strong implications for information provision to potential irrigators in Tasmania. The investment decisions being considered will significantly impact local livelihoods and identities. Information to encourage investment should therefore go beyond short-term marginal benefits. My findings (Chapter 4) indicate that potential irrigators could benefit from the experiences gained by irrigators in the adjacent valley over time. Looking back, these now experienced irrigators wished they had such information when they were considering investing, in other words, insight on what ended up counting for them. Things that counted for these irrigators included personal risk perceptions, perceived stress levels, additional costs, and flexibility to wait for better market prices.

A policy implication, applicable beyond the present case studies, is that policymakers, water managers, and farmers should recognize that reasoning and knowledge, as well as demand and willingness to pay, will change over time. Therefore, it is important to allow room for learning from and with each other, and to design and manage regional water systems with flexibility to cope with future unknowns. We face changes in climate, the environment, technologies, and societal preferences. These changes have been acknowledged in both the Netherlands (e.g., Van Alphen (2016); ZON & DHZ (2015) and Tasmania (e.g., Leith et al. (2019) but are seldom adequately addressed (Lane, 2014). Based on the findings of this research, I recommend incorporating the coupled nature of human-water systems in adaptive approaches for designing and managing regional water systems. Adaptive approaches to managing regional water systems allow farmers, together with others, to influence the water system now and in the future and contribute to long-term system-level objectives.

This has many, context-specific policy implications. One of these is the need to set long-term objectives in a broadly shared way. Path dependencies and potential lock-ins stand in the way of long-term goals, but can be overcome by strategic regulation of regional water markets and also by recurrent workshops aimed at social learning among stakeholders.

These findings overall suggest that water management strategies should place more emphasis on processes to foster social learning. This research found ways to overcome differences in backgrounds, expertise, and scopes of involvement in a deliberative setting that produced a rich set of perspectives benefiting all stakeholders. Participatory workshops, such as those described in this thesis, can enrich the knowledge of all stakeholders, not only farmers but also policymakers. In line with Ridder et al. (2005), I acknowledge that there is no best tool to enhance social learning. I therefore recommend that participatory crossover analysis be added as one of the tools in the social learning toolbox, to foster learning together, to better use, manage, and govern water together.

7.5. FINAL CONCLUSIONS

Water systems are both natural and social, and always evolving. To help manage and steer water systems towards a desirable state, farmers are increasingly being called upon: farmers as water managers. Through on-farm soil and water management and investment decisions, farmers influence their own water availability; but their local interventions also have system-level implications. Farmers can, for example, contribute to long-term objectives, such as improving the ‘sponge capacity’ of a region (the Netherlands) and increasing agricultural value through irrigation (Tasmania).

This thesis concludes that the system-level implications of local interventions are not yet adequately considered in storage assessment tools. I recommend that regional storage assessment tools and processes shift their focus from local storage potential to feasibility. Feasibility is influenced by the spatial and temporal scales of analysis and is context specific. To play their role in regional water management, farmers are often required to make substantial investments, for example, in installing new, on-farm infrastructure. Farmers’ willingness to invest in local interventions hinges on the perceived and projected benefits of additional water and on farmers’ personal preferences, which are influenced by difficult-to-quantify factors, such as risk aversion and personal values.

This research explored whether and when an investment was viewed as ‘worth it’. For farmers, ‘worth it’ turned out to be personal and subject to change. In three case studies, workshop participants engaged in dialogues focused on elicited individual value determinations and the origins of differences within the group. The cases revealed the non-uniformity of farmers’ preferences for various water sources, and the variety of the personal logics underlying farmers’ decisions to invest (or not to invest) in extra water for irrigation. Most participants found sharing and discussing personal reasonings and comparing these with others’ to be meaningful. The workshops built farmers’ confidence and increased their capacity to make better informed individual decisions, while providing water managers and policymakers with insights to improve management and governance. I conclude that participatory water valuation workshops are not only useful for their valuation outcomes, but that they also have the ability to foster social learning among participants.

Building on insights from the participatory workshops, this thesis presents a conceptual approach for adaptive design and management of regional water systems, such as irrigation schemes. I conclude that ongoing social learning among stakeholders is imperative for managing and governing water systems. Adaptive approaches to water management allow farmers, together with others, to influence the regional water system now and in the unfolding future.

APPENDIX I

Table AI.1. Conclusions and recommendations for further research of articles referring to van der Zaag and Gupta (2008) but not directly relate to their call for research on the regional effects of local water storage.

Article	Conclusions and recommendations
(Ghimire & Johnston, 2019)	Ghimire and Johnston (2019) present an assessment to score the sustainability of agricultural systems. The sustainability score includes rainwater harvesting techniques and well-water systems. No mentioning of challenges in assessing the cumulative effects of these systems are mentioned
(Rufin et al., 2018)	Rufin et al. (2018) compare cropping frequencies of irrigation dams command areas. As this is a global assessment, their understanding of a small dam is everything less than 7.9 Mm^3. They recommend future research to focus on water losses and local access to irrigation water.
(Ouma, 2016)	Ouma (2016) compares two techniques to find the most suitable location for a large dam in Uasin Gishu County in Kenya. His contribution is estimating site feasibility, including storage potential but does not consider system interactions.
(Duvail et al., 2014)	Duvail et al. (2014) make use of a participatory monitoring systems to collect water levels in nine lakes, rainfall and food data. In addition, they use a simple water balance model to explore the influence of a planned large dam at Stiegler's Gorge in Tanzania and find that the lake levels are sensitive to changes in flow and precipitation. The authors argue that their approach may help local users to better understand the hydrological system and to adjust to changes but highlight that judicial imperfections and power imbalances hamper the influence of local users in their case study.

(Norman et al., 2013)	Norman et al. (2013) develop the Water Security Status Indicators (WSSI) method for assessing water security and apply the model in a case study area in British Columbia (Canada). Their assessment does not include water storage.
(Pandey et al., 2013)	Pandey et al. (2013) show that an on farm storage increases the benefits of rain fed agriculture in a case study area located in the Indo-Gangetic Plain of India. Harvesting rainwater provides supplemental irrigation, and increases downstream ground water availability in their case study. The authors focus on crop yields and find large differences in the benefits of local storages between wet and dry seasons. The authors assess a single storage and do not discuss further implications of a set of storages.
(Masih et al., 2011)	Masih et al. (2011) calculate the downstream effects of increasing water consumption in the Karkheh Basin, Iran. They find that converting rain fed-fed areas to irrigated agriculture reduces flows downstream. The authors focus on the downstream impacts of irrigation and recommend to exploring the impact of storages in future research. Their paper is a chapter in Masih's PhD thesis (Masih, 2011).
(Love et al., 2011)	Love et al. (2011) employ a water balance model to determine the potential for expanding irrigation and to explore water allocation options in the Limpopo Basin, Zimbabwe. Their model includes both surface- and groundwater resources to explore conjunctive use of surface reservoirs and alluvial aquifers. They find that irrigation can be expanded with the existing dams when making better use of ground water. The authors recommend future studies to investigate water supply from alluvial aquifers when considering the building a new dam.
(Merrey, 2009)	Merrey (2009) argues transnational river basin management institutions will acquire more of legitimacy and effectiveness if they build on African institutional processes i.e. stronger focus on local knowledge and stakeholder participation. The focus of this paper is institutional and transnational, with no links to local storage.

APPENDIX II

II A. INTERVIEW SETUP

Part 1: Accompanied surveys to obtain the range of values for the initial and operating costs of the various water sources and how they are used by farmers.

General on property

-What crops and pastures do you grow?

-On how many hectares or on what area (1 ac = 0.4 ha)?

-How many hectares do you have in total?

-What is the storage capacity of your system? (Farm dam) (ML = 1000 m3 = 100 mm/ha = 250 mm/ac)

-What role does the farm dam play in your water supply system?

-What types of irrigation do you use for your different enterprises?

-How much water do you use for irrigation per year?

-How does that vary over the years (min/max)?

-How valuable is water for your different enterprises?

-How much value do you generate per ML?

Water sources

-What sources of water are available to you?

-What sources of water do you use? We need to understand why, thus the following questions:

-What are important factors to you when considering different water sources (quality, quantity, security)?

-What are the costs of each source? Let's break these costs down to various components.

-What are the initial costs: water rights, construction costs for infrastructure (including drip lines, pumps and/or irrigators of various sorts)?

-What are the operating costs over the lifespan of the system (How often do you replace parts of the infrastructure? How long will the infrastructure last? What maintenance is required? What is the rate of return on investments? What other costs are involved in getting your water "to the right place at the right time"?

-How did these costs change in the past? How do you think they will change in the future?

Comparing sources

-How reliable are your different sources, and how does this affect your usage of them?

-What are the benefits of each source?

-How did these benefits change in the past? How do you think they will change in the future?

-What are the risks of each source?

-How did these risks change in the past? How do you think they will change in the future?

Part 2: Semi-structured interviews to understand context and design for a hypothetical farm

-What is your preferred water source? Why?

-How can you increase water availability on your farm?

-What are relevant water sources that could become available in the near future?

-What farm characteristics define water demand?

Interviewer explained crossover approach and asked for input:

During the cross-over session, you will discuss the ranking of different water sources, based on the relevant cost and benefit components. We will focus on the questions: "Under what condition would your initial ranking change? How robust are your current *preferences? Why do you prefer certain water sources, and how could this be taken into account when designing a new scheme or expanding current sources?*

For the proposed workshop, we still have scope to change things to make sure it is relevant to you. We are thinking about using a hypothetical farm as a basis for discussion and analysis. We will start from scratch and assume that all or most sources are available. What would be the types of costs of the different sources, and what would be the amount of water needed to irrigate certain crops? Or, if you were the owner of this farm, what sources of water would you invest in and why? What would the hypothetical farm look like and what sources and strategies for water supply would be relevant?

Another option would be to discuss water sources by focusing on production. We could say, we generally have three categories of production, those being perennial horticulture (cherries, grapes, etc.), mixed crops (seed crops, poppies, cereals, etc.), and livestock (sheep, lamb, cattle). Let's say we deal with them separately, as they are very different enterprises. So, if you grew cherries or grapes on, let's say, 10 hectares, how much water do you need and what water source would you like best?" (Same for mixed crops and livestock)

-How do you think that water availability could change in the Coal River Valley in the future? Why do you think that? How will you respond to those changes?

-Where do you see your farm in 20 years' time? How do you think the Coal River valley will develop?

II B. GROUP EVALUATION QUESTIONS AND OUTCOMES

Table AII B.1. Results from the evaluation immediately after the irrigator workshop at the University Farm.

	Environment				
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I felt comfortable talking honesty about my preferences.	0	1	0	6	4
I believe others in the group were consistently honest throughout the workshop.	0	0	1	10	0
I felt comfortable talking about my reasoning for preferences.	0	0	1	8	2
The workshop facilitation was appropriate for the content and group.	0	0	0	10	1
	Workshop				
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
If I talk about the workshop to other people it will mostly be positive.	0	0	4	7	0
The outputs of this workshop should be interesting to other audiences.	0	0	3	7	1

	Variable	Very slow	A bit slow	About right	A bit rushed / Too fast
The pace of the workshop was:	2	0	1	8	0
	Crossover points (Willingness to pay)				
	I hadn't really ever thought about it	About the same as I expected	Slightly different from what I expected	Very different from what I expected	
On average, other people in the group had preferences that were:	3	4	4	0	
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The crossover approach has added something to the way I will think about water investment decisions.	0	1	3	7	0
The crossover process helped to inform my thinking about water investment decisions.	0	0	2	8	1
The crossover framework is a valuable way to guide group discussion.	0	0	3	6	2

II C. GUIDE FOR FOLLOW-UP EVALUATION PHONE CALLS, 3–5 WEEKS AFTER THE WORKSHOP

(This first question uses an inductive open-ended approach to elicit stand-out memories and take people back to the event and the discussion going on there.)

1) Ok, so the first question is about any general reflections on the workshop and the discussions you had last week. Were there any parts of the discussion that stood out or that you remember as particularly useful or interesting? Are there things that surprised you about the perspectives of other people in the group? (Follow-up: Why was that interesting/useful?)

(Question 2 elicits thinking about the use of the process and outputs for learning.)

2) This question is about potential value of the crossover process in meeting its goal of enabling groups to learn and potentially improve decision-making. (The process is understood to extend from the interviews to the workshop and writing up the findings.) So, for the following groups, what do you see as the potential value for learning and decision-making:

	Potential value (learning and decision-making)
For the group of Coal River irrigators (workshop participants)	
Other farmers in Coal River Valley	
Farmers from other valleys who are considering irrigation investments or recently got access to irrigation water	
Policymakers and utilities (e.g., Taswater, Tas Irrigation)	

(Question 3 seeks input for future improvements)

3) Are there any ways that you think the crossover process could be adapted or improved to make it more useful or achieve its full potential?

Other people that you think would have been valuable in the discussion:

	Reason
Other farmers from valley	
Other farmers from elsewhere	
Politicians	
TI	
TAS Water	
DPIPWE	
Others	

- Who should facilitate these discussions? Was it good to have an independent researcher, or could the facilitator be from TI, DPIPWE, or MAQFRANK?
- Discussion Support System and modelling?
- Different presentation formats and tools?

(This fourth question is geared towards impact and robustness, or changes in ways of thinking and deciding.)

4) Did the discussion give you a better understanding of or confidence in your water source preferences? If so, can you say what the influence was?

- Did you get a better understanding of where differences between neighbours in crossover points come from?
- Did you continue the discussion with others?
- Did that produce new answers or insights?
- Would you have filled in other values if you could do it again? If so, for which question and why?

II D. CROSSOVER INDICATIONS

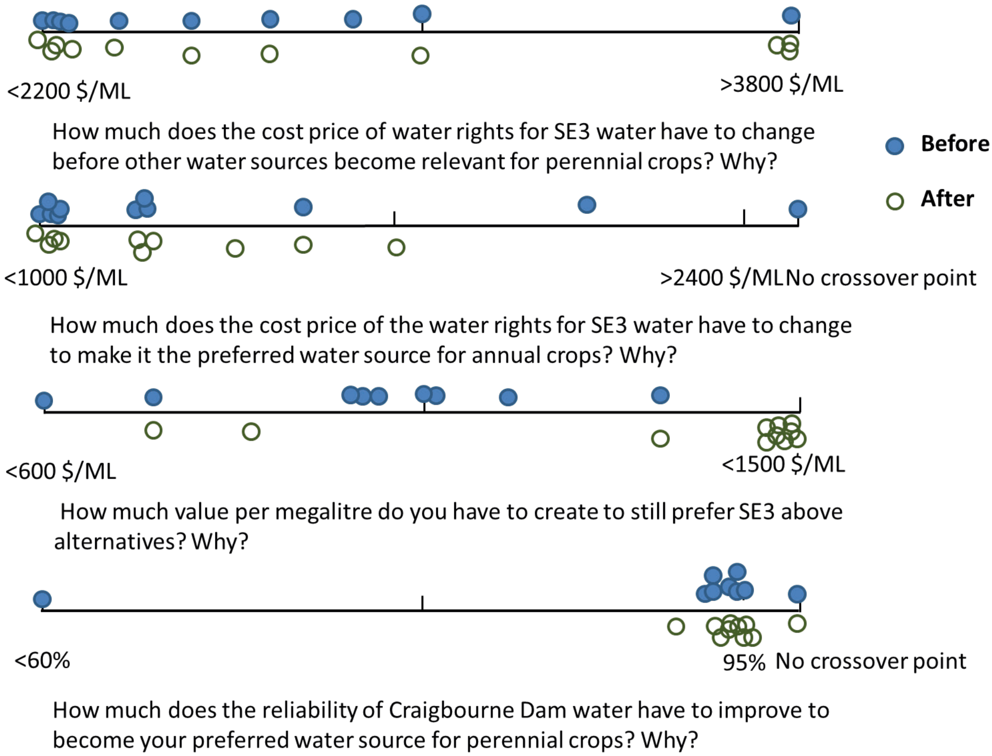

Figure AII D.1. Crossover points of the participants with the crossover point before the discussion above the line and the crossover points after the discussion displayed below the line. The primary intent of asking for crossover points is to start as discussion; crossover points cannot be understood as stand-alone results or willingness to pay. These crossover points are clearly subject to change, case-study dependent, and by no means representative. The Figure just shows the different perspectives within the group. Changes occurring during the discussion might be due to learning but also simply better understanding the question at hand.

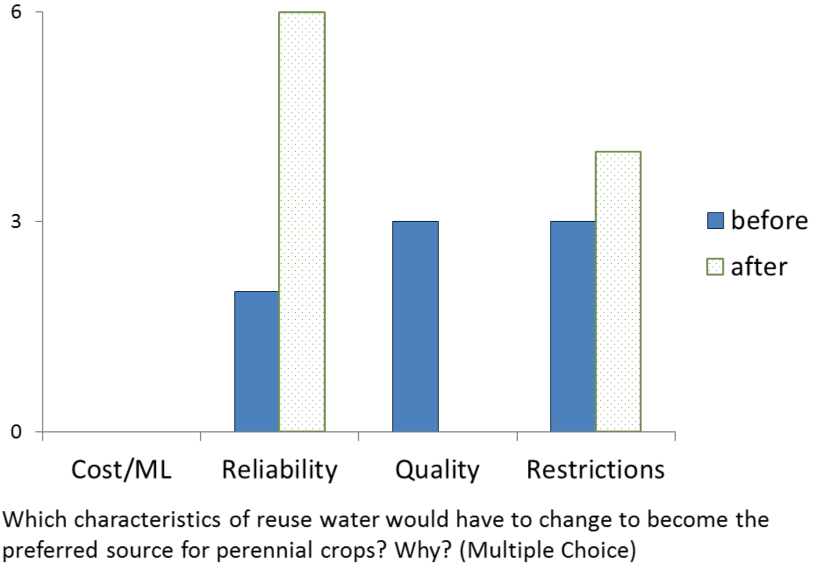

Figure AII D.2. Participants' indications of the most important characteristic of re-use use water before and after discussion.

APPENDIX III

III A. Interview Format

Name **Date**

The interview is set up to explore diversity and to get:

-Better understanding of farming context in the district

-Initial values for irrigation costs

-Initial values for value generated with irrigation water

-Crossover analysis introduced to the participants of the session

Part 1: Accompanied survey

Introduction

These are questions on your property and water entitlement. With your answers, we are not looking for significance but they will shape the discussion in December.

General on property

-How many hectares/acres do you have in total? (1 ac = 0.4 ha)

-How many hectares/acres do you irrigate?

-What crops and pastures do you grow under irrigation?

-On how many hectares or on what area?

Irrigation water

-How many years of irrigation experience do you have?

-What is your current water allocation?

-How much water do you use for irrigation per year?

-How does that vary over the years (min/max)?

-How much value do you currently generate per ML?

-How much value do you want to create in the future?

-What is the zone that you are in?

-How tradeable is your entitlement? (Location dependent) Have you ever traded water?

-What are your yearly costs for water rights?

-What investments did you have to do to start irrigating (capital cost farm dam, infrastructure)?

-How much does it cost you to put a ML on the ground (ongoing cost)?

Part 2: Semi-structured interviews to understand context

Introduction

After gathering information about your farm, I would now like to discuss irrigation water in a broader context.

-What was your reasoning for investing (or not) in SE3 water (return on investment)?

-Where did you get information that helped you with this investment decision? What information did you use?

-Do you wish you had bought more/less? Why?

-Do you often discuss water with other farmers? If yes, what aspects?

-What do you think is the long-term reliability of the scheme?

-Where do you see your farm in 20 years' time?

-How do you think the district will develop?

Introduce crossover and discuss what I want to do in the sessions: *At the session I organized in the Coal River Valley, it turned out that participants had very different perspectives on irrigation water and in what conditions it is worth it to invest in water rights. In this district you just had the situation where you actually had to make this investment decision. In the discussion session in December, we will talk about personal reasoning why you did or did not invest in water. Maybe opinions have changed now? We will discuss in what conditions you believe investing in SE3 water is* *worth it, both based on the costs to buy and operate it and the value you have to generate to make the investment worthwhile.*

Concluding questions

Are you willing to participate in the discussion session? Y/N

We are considering the following dates: 4, 5, or 12 December. Do you have a preference?

III B. Workshop Planning

18:45 for 19:00 start

Facilitator welcomes everyone when entering by shaking hands (acknowledge). Tea, coffee, and Dutch cookies are provided near the entrance so participants can get comfortable and have something to do. Next to the coffee and tea, there will be stickers to make name tags.

19:05

Facilitator starts by thanking everybody for coming and explains the rules/conditions without being directive or demanding: *The interesting part of tonight is talking about reasons behind outcomes and personal preferences. My findings so far suggest that everyone here has personal reasons for what they do. These reasons define personal preferences and investment decisions. Tonight, there is no "best". There is no stupid, or smart. There is no better or worse. Diversity in this group is its biggest asset. Diversity is the key to new insights. I hope that you are curious and open to others. I hope that you are willing to listen and learn so that you leave with new insights, and I hope you are willing to explain and share so that others can learn from you. I will first display some ranges of the answers that I got in the interviews. These interview findings show differences between you, but do not explain where these differences come from. That is what you will discuss in the rest of the session. Is that clear? Are there any questions?*

Clicker question (CQ)

CQ How many of the other participants have you discussed water with?

Would you please introduce yourself: name, type of enterprise, location of farm?

CQ How confident do you feel discussing costs and benefits of irrigation water in this group?

Is there anything we can do here and now to improve the situation before we start discussing?

Display (range of): value generated/ML, years of experience, setup to start with, ML/ha, crops grown, cost to put water on crops (pumping)

Explain the crossover concept and introduce the steps:

First guess, confidence levels, second guess, confidence levels -> discuss changes.

Water-related crossover questions: *From the interviews, I learned that farm location is important. The proximity to residential areas made some of you prefer keeping the option of subdivision open. That is a very important insight and I will report on that, but we will have to take that out of the consideration today. Therefore, today we explore the costs and benefits of irrigation water for a farming future. We first go back in time a bit. Based on what you know now, if the scheme was going to be rebuilt and there was not the option of subdividing your land in the future, what would you have done?*

CQ 1) Wat is the maximum price for a water right that you would be willing to pay per ML?

Follow up

- Is that different now than two years ago?

- Is there anyone here who wished they had bought more, or less? Why? Who bought extra since? Why?

Reliability came up in the interview as a very important characteristic. Let's explore that, and again, I am interested in the reasons why:

CQ 2) How much would you have been willing to pay if reliability would have been 80% instead of 95%? Why?

Follow up

- Would you have bought more? Why?

- How important is reliability? Why?

- How can management affect reliability?

- What if you could order in bulk? Why?

20:00–20:15 Break: coffee, tea and Grolsch

CQ 3) How much are you willing to pay for winter water rights? Why?

Follow up:

- Manageability

- What are the most important differences between winter water and summer water?

- Will non-irrigators buy winter water?

- Is there enough water to facilitate the valley's long-term potential?

CQ 4) How much value/ML do you have to generate to make SE3 water worthwhile? Why?

Follow up:

- Is that possible with livestock? Annual crops? Why? How?

- What are other factors that should be considered? Why?

(Succession, Long-term investment, Value of water security, Risk, Uncertainty, More value generation but not more profit, Change in life, Working at night and in the weekends)

20:45 Evaluation

21:15–21:30 Wrap up

III C. Workshop Evaluation: Follow-Up Evaluation Questions

1. Do you remember the purpose of the workshop? Were there any parts of the discussion that stood out or that you remember as particularly useful or interesting?

2. Are there any ways that you think of that the crossover process could be adapted or improved to make it more useful or to achieve its full potential?

3. Would you recommend the workshop to others? If so, why?

4. Did the discussion give you a better understanding of, or confidence in, your preferences? If so, can you say what this influence is?

5. Any other things you would like to add?

APPENDIX IV

IV A. WORKSHOP PLANNING

Place: Sorell Training Centre

Date: May 2018

18:45 for 19:00 start.

Facilitator welcomes everyone when entering by shaking hands (acknowledge). Tea, coffee and Dutch cookies are provided near the entrance. Next to the coffee and tea, are stickers so participants can write their first names to make name tags. After coffee and tea, in which the participants have the chance to familiarize, they are seated in a half circle with a screen and projector at the open end.

19:05

Facilitator starts by thanking everybody for coming and explains the rules/conditions and the aim without being directive/demanding:

"The aim of tonight is to support a dialogue among farmers, water managers, and policy makers about the costs and benefits of irrigation water, in order to learn from each other's insights, and reasoning. This means that there no best, or optimum or right or wrong. The previous discussions showed that everyone had personal reasoning that was different from their neighbours. If you bring people with different backgrounds together, it is likely that their reasoning is quite different which might be interesting for the discussion. So, tonight we will find out if it actually works to talk about water and the price of irrigation water among people with a different background. We will make use of crossover points. Crossover points or tipping points are the point where two alternatives have the same preference. It is a maximum or minimum you are willing to pay. The points provide limited insight. They are used as strawmen to encourage personal reasoning. The dialogue of tonight is informal, non-binding and we are not seeking consensus. We do not have to agree with each other. It

is about sharing. You take with you what you want and leave this room again. We do not have to find solutions, or become best friends. I hope to provide an opportunity in which we can talk freely about personal perspectives. Is that clear? Are there any questions?"

Clicker question (CQ)

CQ Ice breaker question

French fries are best with? Mayonnaise / Ketchup / Curry Gewurz / Satay Sauce / Mayonnaise, Ketchup and Onions / Gravy / Gravy and cheese curds / No sauce / I just nibble on raw veggies, seeds, and nuts

CQ Dialogue conditions

I feel comfortable to talk about the cost and benefits of irrigation water in this group? Strongly agree / Agree / Neither agree nor disagree / Disagree / Strongly disagree

Is there anything we can do here and now to improve the situation before we start discussing?

Explain the crossover concept and introduce the steps.

Display Table with characteristics of water sources and discuss.

Table IV A.1 Characteristics of water sources

		Craigbourne Dam	**SE3**	**Reuse**
Costs	Capital costs/ML (water rights)	$1000-$2500	$2500-$2700	0
	Annual costs/ML	$105 plus pumping (up to $150)	$140 fixed + $178-$220 variable	$10-$70 (plus pumping)
Quality		Variable but often too poor/salty for sensitive crops	Almost drinking water quality	Comes with restrictions on use
Reliability		60-90%	95%	80-99%

Crossover Question (CQ) 1 What is the maximum price for a water right that you/a farmer can pay for water that is provided with 95% surety and of high quality? Why?

Follow up:

-How do yearly costs influence the willingness to pay for water rights?

-What do you know now that you wished you knew when setting up (scheme, policy, on farm)?

-What caused this change in thinking?

-How did perspectives change?

CQ 2 What is the maximum price for a water right that farmers could be paying for water that is provided with 95% surety and of high quality in 10 years from now? Why?

Follow up:

-What does this mean for water governance? And water managers?

-How can the current design strategy be improved?

-What sort of information would be helpful for farmers that get the opportunity to buy water in the future?

-What is the long term water demand in the valley?

20:00-20:15 Break: coffee, tea and Grolsch

CQ 3 What is the maximum price for a water right that you/a farmer can pay for water that is provided with 80% surety and of high quality? Why?

Follow up:

-What does 80% mean?

-What is surety? What is reliability?

-How does surety affect planning?

CQ 4 What is the maximum price for a water right that you/a farmer can pay for water that is provided with 95% surety and of high quality, provided in the winter? Why?

Follow up:

-Manageability

-What are the most important differences between winter water and summer water?

-Will current non irrigators buy winter water?

-Is there enough water to facilitate the valley's long term potential?

CQ 5 How much value/ML do/does you/a farmer need to generate to make water of $ 2700/ML worthwhile? Why?

Follow up:

-Is that possible with live stock? Annual crops? Why? How?

-What can be learned from the coal river/SE3 experience?

-Is the coal river/SE3 relevant for other valleys in the State?

21:00 Evaluation

21:30-21:45 Wrap up

IV B. GROUP EVALUATION QUESTIONS AND OUTCOMES

Table AIV B.1. Exit survey and workshop reflections

	Drivers				
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
I felt comfortable to participate in the dialogue.	0	0	1	1	6
I believe others in the group were consistently honest throughout the workshop.	0	0	0	2	6
I felt able to talk honestly throughout the session talking about my reasoning for preferences.	0	0	0	2	6
The focus on crossover point is a valuable way to guide group discussion.	0	0	5	3	0
I would recommend this workshop to others.	0	0	0	5	3
The workshop facilitation was appropriate for the content and group	0	0	0	5	3
	Too fast	A bit rushed	about right	A bit slow	Very slow/ Variable
The pace of the workshop was	0	0	8	0	0

	Outcomes				
	I hadn't really ever thought about it	About the same as I expected	Slightly different from what I expected	Very different from what I expected	
Other people in the group had crossover points that were:	0	0	5	3	
Other people in the group had reasoning that was:	0	5	3	0	
	Strongly disagree	Disagree	Neither agree nor disagree	Agree	Strongly agree
The workshop helped to inform how I value water.	0	0	1	4	3
The outputs of this workshop should be interesting to other audiences.	0	0	1	3	3
The crossover process helped to inform my thinking about the costs and benefits of water.	0	0	0	5	3
If I talk about the workshop to other people it will mostly be positive	0	0	0	3	5

IV C. PERSONAL FOLLOW-UP EVALUATION QUESTIONS THREE TO FIVE WEEKS AFTER WORKSHOP

(The following questions seek to eliciting stand-out memories and get people back to the event and the discussion that was going on there through an inductive open ended approach)

1) What are the parts of the discussion that stood out or that you remember as particularly useful or interesting?

2) What did you learn during the workshop?

3) How do you look back on the workshop? [Follow-up: Why was it valuable/useful/interesting?]

(These questions elicits thinking about the use of process and outputs for learning)

4) What or how did the cross-over points add to the group discussion?

5) Why are crossover points a valuable way to guide group discussion, or why not?

(These questions get towards impact and robustness: change in ways of think and decide)

6) Would you recommend the workshop to others? If so, why?

7) Did you continue the discussion or the thinking process?

8) -Did this lead to different answers/insight?

9) -Would you have filled in other values if you could do it again? If so, for which question and why?

10) Are there any ways that you think the cross-over process could be adapted/ improved to make it more useful or to achieve its full potential?

-Tips/Tops

IV D. INTERVIEW QUESTIONS SIX MONTHS AFTER WORKSHOP

Introduction question

1) If you go back to the workshop in May, what stood out or that you remember as particularly useful or interesting?

Drivers

2) Would you be willing to participate in similar workshop in the future? Why? Why not?

3) Did you appreciate "the way" we talked? Why? Why not? What made it that you appreciated it?

Relational outcomes

4) Did the workshop extend your network? If so, who did you not know before?

5) Did the workshop make it easier to collaborate with other participants in the future? If so, why?

Shared understanding and substantive outcomes

6) Did the workshop result in any tangible outcomes such as initiation of projects / actions / follow-ups?

7) Would similar workshops be beneficial for the water sector? Farmers, managers, policymakers? Why, Why not?

8) Are there any other outcomes that you connect to this workshop? If so, how and why?

9) What made it that you valued the workshop (or not) and how did the method contribute to that value?

10) Did we miss anything in the evaluation? Or anything you want to say about the process?

IV E. WATER RELATED DISCUSSIONS/INSIGHTS FROM THE WORKSHOP

1 What is the maximum price for a water right that you/a farmer can pay for water that is provided with 95% surety and of high quality? Why?

- If having to change enterprise, the cost of water rights may be only half of the total transition costs.
- If just 10 ML of high security water is added to an existing water allocation, it can provide an insurance policy. It then has value and influence on operational choices that go beyond that 10 ML and might therefore be valued differently (higher).
- The value of water is market driven and changes over time: “Today, we are basing our decision on what we know now but we already have seen a major shift even since SE3”.
- In some situations, “the value of the water outweighs the dollar value that is put on it”.
- Yearly operational costs are of major importance when making an investment decision as it needs to be covered in the yearly budget by the crop that is grown with irrigation water. The combination of water rights and yearly cost determines the (need for) change in enterprise.
- There are many social factors that determine the value of water. Over time, the value of water changes as people change their expectations and perspectives about what they can do with water. However, investment decisions are based on what people know at the time of investment.
- Shifting from dry land to irrigation changes comes with lifestyle changes as the energy tariffs (i.e. low cost power) force farmers to work on the weekends. This has strong implications for family life.
- Long term value of water rights is a different line of thought than growing something (making a profit) with that water. Value determination is a personal combination of both long and short term reasoning.

- Investing in water is believed to be a good long term investment as the market price for water rights is assumed to go up.

2) What is the maximum price for a water right that farmers could be paying for water that is provided with 95% surety and of high quality in 10 years from now?

- The value of water is changing rapidly, demanding major adjustments in how it is governed and managed. If there are no significant changes in the availability of water, the cost price of water rights will substantially increase, see Figure 5C1. This notion comes with governance challenges related to accountability, market regulation, and (long term) planning. Increasing water prices will challenge the long term Ag 2050 vision.
- Current water availability will put a ceiling or "cap" on the agricultural output of the valley.
- Water demand in Tasmania might be influenced by enterprises from the Murray Darling Basin that (need to) move to Tasmania. Various reasons and potential consequences were mentioned.
- Water prices and the willingness to pay for water have changed rapidly in the last 10 years. In the last 10 years, the market went from handing out allocations for free, to now selling water for $5000/ML as the highest outlier. The droughts of 2000 and 2008 are mentioned as years in which perceptions changed.
- Metering water uptake at farm level is imperative to improve water management at water-system level.
- Despite the increase in overall water use in the area, there are fewer enterprises irrigating.
- In the long term, a higher willingness to pay for water might provide enough demand to cover the cost of building another irrigation scheme.
- The government has an important role to facilitate water markets. A long term view of the preferred state of water as a precious resource is crucial.

- Some potential buyers cannot come up with the capital to invest in water rights. A deferred payment, in which a percentage of the upfront cost for water rights could be paid five years after the start of the operation, would allow growers the time to change enterprise. A deferred payment system was discussed as a promising option to increase the initial uptake.
- Investing in expensive water limits the transformation capacity to change current business, i.e. to become more intensive or to chase a market opportunity that requires capital investments other than water.
- Water demand, and with that the potential to grow more high value crops, increases over the years due to experience.
- All participants agree that forward looking and exploring the future use of water before building an irrigation scheme is essential. Participants called this exploration “future proofing” and “no-regret design decisions”.
- If people were encouraged to think more broadly about the (potential) value of water, they might buy more water when a new irrigation scheme is built. A learning process may increase initial water demand.
- A subsidy from the government to decrease the price of water might be perceived by the community as a transfer of wealth to the current land holders.
- The government investing in extra scheme capacity might become profitable when this water is sold at a later stage (when prices are higher). It is then an investment rather than a subsidy.
- Reuse water provides an additional source for enterprises that cannot afford high value water.

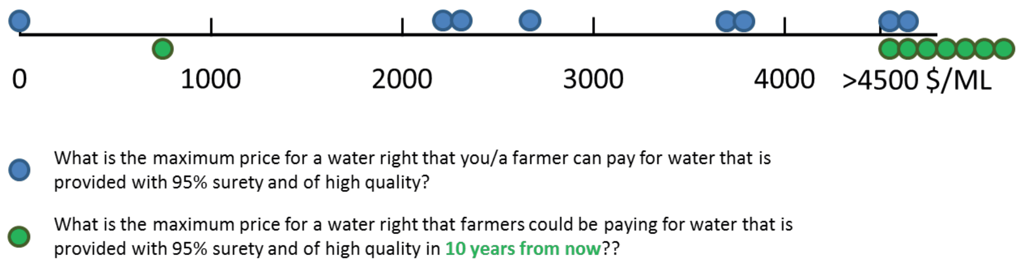

Figure AIV E.1. Difference between willingness to pay now (blue crossover points) and the expected price rise (green crossover points)

In the South East Irrigation District, various water sources are available. These sources vary in water quality, reliability, tradability, and costs. The next three questions focus on how and why characteristics of water change the willingness to pay for this water. Indicated crossover points are displayed in Figure 5C2.

3) What is the maximum price that you or a farmer can pay for water that has 80% surety and is of high quality? (So no longer 95% but 80%).

- It is unclear what the definition is of 80% surety. "Does 80% mean you won't get any water, or you still get a certain amount but not your full allocation?" If 80% means one year out of 5 you do not get water, it is not suitable for perennial crops.
- 80% can mean different things. For example, with reuse water, you do not know when water will be supplied (high uncertainty) but there is high certainty that you will get you full allocation during the growing season.
- Surety turned out to be the wrong word to use. Surety means you get 100% in 95% of the years and you do not get any in the other 5%. The practical meaning of 95% reliability is that you get at least 95% of the water in 100% of the years. Surety is not a word used in the contracts of TI.
- Reliability is context specific. The effect of low or high reliability on the willingness to pay for water is a personal matter in which participants expressed different opinions.

- The opportunity to trade water seems vital. In the SE3 scheme, tradability of water depends on farm location within the scheme. Farmers with perennials will buy water from farmers with annual crops when water becomes scarce. Whether or not there is a functioning water market heavily influences the willingness to pay for water of 80% reliability. Currently the trading market is not fully established.
- With lower reliabilities, having an on-farm buffer in the form of an on-farm dam becomes crucial. The cost of on farm storage dependents on location. The best location for a dam might also be the best land to grow crops.

4) What is the maximum price for a water right that you/a farmer can pay for water that is provided with 95% reliability and of the quality of reuse water?

- It is suggested that water in farm dams in the South East is often of too low quality, too salty, to be used for sensitive crops.
- Reuse water comes with strict regulations. These regulations constrain how, when, where, and on what crops farmers can use reuse water. These constraints heavily influence the willingness to pay. An example is that farmers cannot have cattle on fields recently irrigated with reuse water.
- With the current water treatment systems, the regulations on reuse water are perceived as necessary.
- Reuse water contains valuable nutrients, but most of the nutrients are lost during (on-farm) storage.
- Although reuse water has a lot of potential for the South East, with its proximity to Hobart, most reuse water is currently not suitable due to salty seawater intrusion into the scheme. Intrusion problems have to be fixed in order to become a viable source for irrigation.

5) What is the maximum price for a water right that you/a farmer can pay for water that is provided with 95% reliability and of high quality, provided in the winter?

- The difference between water supplied in the winter, versus water supplied in summer is said to be the cost of storage plus losses due to leakage and evaporation. The cost of storing water is location dependent.
- The value of winter water is correlated with the value of summer water. Some participants argued that the market price for winter water should be significantly less than water supplied in the summer. However, others argued that having a full dam at the beginning of spring is worth a lot.
- With 95% reliability, and water supplied in the summer, you only need a small farm dam. Water supplied in the winter (all) needs to be stored. The cost of a large dam versus a small dam is again location specific.
- Currently, the SE3 summer water is supplied from October to March. Recycled water is supplied all year, and there are increasing demands for water in the shoulder seasons (Sept and April/May). The demand for water in the shoulder season, related to a changing climate, future growing seasons and crop choice will influence the value of water supplied in winter.

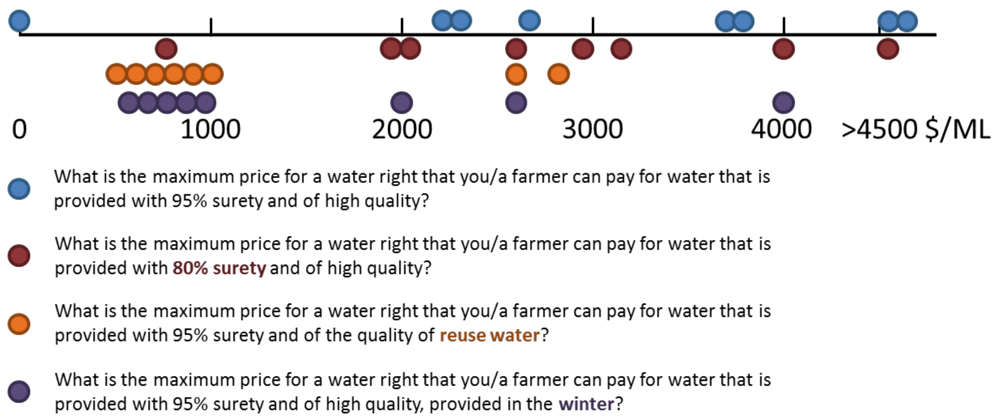

Figure AIV E.2. Crossover points, illustrating the influence of characteristics on willingness to pay.

REFERENCES

Aarts, N. (1998). *Een kwestie van natuur: een studie naar de aard en het verloop van communicatie over natuur en natuurbeleid.* (PhD). Wageningen University, Wageningen, the Netherlands.

ABC News. (2019a). Satellite images question how private dams filled during Murray-Darling pumping embargo. Retrieved from https://www.abc.net.au/news/2019-10-18/satellite-images-question-how-private-dams-filled-murray-darling/11617320

ABC News. (2019b). Irrigators slam Murray-Darling Basin Authority for releasing satellite images. Retrieved from https://www.abc.net.au/news/2019-10-19/irrigators-slam-murray-darling-basin-authority/11619354

AgriGrowth Tasmania. (2016). *Tasmania's Sustainable Agri-Food Plan 2016 - 2018*. Retrieved from Hobart, Australia:

AgriGrowth Tasmania. (2017). *Growing Tasmanian Agriculture – Research, Development and Extension for 2050 Green Paper*. Retrieved from Hobart, Australia:

Aki, H., Oyama, T., & Tsuji, K. (2006). Analysis of energy service systems in urban areas and their CO2 mitigations and economic impacts. *Applied Energy, 83*(10), 1076-1088. https://doi.org/10.1016/j.apenergy.2005.11.003

Alamanos, A., Mylopoulos, N., Loukas, A., & Gaitanaros, D. (2018). An Integrated Multicriteria Analysis Tool for Evaluating Water Resource Management Strategies. *Water, 10*(12), 1795. https://doi.org/10.3390/w10121795

Allan, C., & Curtis, A. (2005). Nipped in the Bud: Why Regional Scale Adaptive Management Is Not Blooming. *Environmental Management, 36*(3), 414-425. https://doi.org/10.1007/s00267-004-0244-1

Arshad, M., Guillaume, J. H. A., & Ross, A. (2014). Assessing the Feasibility of Managed Aquifer Recharge for Irrigation under Uncertainty. *Water, 6*(9), 2748-2769. https://doi.org/10.3390/w6092748

Australian Academy of Science. (2019). *Investigation of the causes of mass fish kills in the Menindee Region NSW over the summer of 2018–2019*. Retrieved from Canberra, Australia: https://www.science.org.au/supporting-science/science-policy-and-sector-analysis/reports-and-publications/fish-kills-report

Australian Bureau of Statistics. (2013). Retrieved from http://www.abs.gov.au/AusStats/ABS@.nsf/MF/5220.0

Australian Government. (2015). *Building the infrastructure of the 21st century*. Retrieved from Canberra, Australia: https://agwhitepaper.agriculture.gov.au/sites/default/files/SiteCollectionDocuments/ag-competitiveness-white-paper.pdf

Australian Government. (2016). *Project Agreement for Tasmanian Irrigation Tranche II*. Retrieved from https://www.agriculture.gov.au/water/national/tasmania/tasmanian-tranche-ii-agreement

Bandura, A. (1977). *Social learning theory*. Englewood Cliffs, New Jersey, USA: Prentice-Hall.

Barnett, J., Graham, S., Mortreux, C., Fincher, R., Waters, E., & Hurlimann, A. (2014). A local coastal adaptation pathway. *Nature Climate Change, 4*, 1103–1108. https://doi.org/10.1038/nclimate2383

Barraclough, R. (2013). Social Learning and Deliberative Democracy. In L. Shultz & T. Kajner (Eds.), *Engaged Scholarship: The Politics of Engagement and Disengagement* (pp. 107-120). Rotterdam, the Netherlands: SensePublishers.

Bateman, I. J., Carson, R. T., Day, B., Hanemann, M., Hanley, N., Hett, T., . . . Pearce, D. W. (2002). *Economic valuation with stated preference techniques: A manual*. Cheltenham, UK: Edward Elgar.

Birol, E., Karousakis, K., & Koundouri, P. (2006). Using economic valuation techniques to inform water resources management: A survey and critical appraisal of available techniques and an application. *Science of The Total Environment, 365*(1), 105-122. https://doi.org/10.1016/j.scitotenv.2006.02.032

Blanc, E. (2014). Is Small Better? A Comparison of the Effect of Large and Small Dams on Cropland Productivity in South Africa. *World Bank Economic Review, 28*(3), 545-576. https://doi.org/10.1093/wber/lht026

Bloemen, P., Reeder, T., Zevenbergen, C., Rijke, J., & Kingsborough, A. (2018). Lessons learned from applying adaptation pathways in flood risk management and challenges for the further development of this approach. *Mitigation and Adaptation Strategies for Global Change, 23*(7), 1083-1108. https://doi.org/10.1007/s11027-017-9773-9

Boelens, R. (2014). Cultural politics and the hydrosocial cycle: Water, power and identity in the Andean highlands. *Geoforum, 57*, 234-247. https://doi.org/10.1016/j.geoforum.2013.02.008

Boelens, R., Hoogesteger, J., Swyngedouw, E., Vos, J., & Wester, P. (2016). Hydrosocial territories: a political ecology perspective. *Water International, 41*(1), 1-14. https://doi.org/10.1080/02508060.2016.1134898

Boelens, R., Shah, E., & Bruins, B. (2019). Contested Knowledges: Large Dams and Mega-Hydraulic Development. *Water, 11*(3), 416. https://doi.org/10.3390/w11030416

Bohm, D. (2004). *On dialogue*. London, UK: Routledge.

Boles, K. E., & Fleming, S. T. (1996). Breakeven under capitation: pure and simple? *Health Care Manage Rev, 21*(1), 38-47.

Bos, J. J., Brown, R. R., & Farrelly, M. A. (2013). A design framework for creating social learning situations. *Global Environmental Change, 23*(2), 398-412. https://doi.org/10.1016/j.gloenvcha.2012.12.003

Bosomworth, K., Leith, P., Harwood, A., & Wallis, P. J. (2017). What's the problem in adaptation pathways planning? The potential of a diagnostic problem-structuring approach. *Environmental Science & Policy, 76*, 23-28. https://doi.org/10.1016/j.envsci.2017.06.007

Brugnach, M., Dewulf, A., Pahl-Wostl, C., & Taillieu, T. (2008). Toward a relational concept of uncertainty: about knowing too little, knowing too differently, and accepting not to know. *Ecology and society, 13*(2), Art. 30-Art. 30. Retrieved from http://edepot.wur.nl/24441

Budds, J. (2009). Contested H2O: Science, policy and politics in water resources management in Chile. *Geoforum, 40*(3), 418-430. https://doi.org/10.1016/j.geoforum.2008.12.008

Bull, R., Petts, J., & Evans, J. (2008). Social learning from public engagement: dreaming the impossible? *Journal of Environmental Planning and Management, 51*(5), 701-716. https://doi.org/10.1080/09640560802208140

Burgess, J., Clark, J., & Harrison, C. M. (1998). Respondents' evaluations of a CV survey: a case study based on an economic valuation of the Wildlife Enhancement Scheme, Pevensey Levels in East Sussex. *Area, 30*(1), 19-27. http://doi.org/10.1111/j.1475-4762.1998.tb00044.x

Carpenter, S., Folke, C., Scheffer, M., & Westley, F. (2009). Resilience: accounting for the noncomputable. *Ecology and society, 14*(1). www.ecologyandsocietyorg/vol14/iss1/art13/

Carson, R. T., Groves, T., & List, J. A. (2014). Consequentiality: A Theoretical and Experimental Exploration of a Single Binary Choice. *Journal of the Association of Environmental and Resource Economists, 1*(1/2), 171-207. http://doi.org/10.1086/676450
Choi, I.-C., Kim, H. N., Shin, H.-J., Tenhunen, J., & Nguyen, T. T. (2016). Willingness to Pay for a Highland Agricultural Restriction Policy to Improve Water Quality in South Korea: Correcting Anomalous Preference in Contingent Valuation Method. *Water, 8*(11), 547. https://doi.org/10.3390/w8110547
Cleary, C., Hardie, S., Morrison, B., Aldridge, A., & Pryor, S. (2018, August). *Collaborative water management in the Ringarooma River catchment Tasmania, Australia.* Paper presented at the 9th Australian Stream Management Conference, Hobart, Tasmania.
Collins, K., & Ison, R. (2009). Jumping off Arnstein's ladder: social learning as a new policy paradigm for climate change adaptation. *Environmental policy and governance, 19*(6), 358-373. https://doi.org/10.1002/eet.523
Connell, D. (2011). Water Reform and the Federal System in the Murray-Darling Basin. *Water Resources Management, 25*(15), 3993-4003. https://doi.org/10.1007/s11269-011-9897-8
Costanza, R., d'Arge, R., De Groot, R., Farber, S., Grasso, M., Hannon, B., . . . Paruelo, J. (1997). The value of the world's ecosystem services and natural capital. *Nature, 387*(6630), 253. https://doi.org/10.1038/387253a0
Costanza, R. (2000). Social goals and the valuation of ecosystem services. *Ecosystems, 3*(1), 4-10. http://doi.org/10.1007/s100210000002
Cradock-Henry, N., Frame, B., Preston, B., Reisinger, A., & S. Rothman, D. (2018). *Dynamic adaptive pathways in downscaled climate change scenarios*.
Cundill, G., & Rodela, R. (2012). A review of assertions about the processes and outcomes of social learning in natural resource management. *Journal of Environmental Management, 113*, 7-14. https://doi.org/10.1016/j.jenvman.2012.08.021
Davidson, B., Hellegers, P., & Samad, M. (2009). *Assessing the economic impact of redistributing water within a catchment: a case study of the Musi Catchment in the Krishna Basin in India*. Retrieved from Colombo, Sri Lanka: http://dx.doi.org/10.3910/2010.005
Davidson, B., Hellegers, P., & Namara, R. E. (2019). Why irrigation water pricing is not widely used. *Current Opinion in Environmental Sustainability, 40*, 1-6. https://doi.org/10.1016/j.cosust.2019.06.001
de Fraiture, C., Wichelns, D., Rockström, J., Kemp-Benedict, E., Eriyagama, N., Gordon, L. J., . . . Karlberg, L. (2013). Looking ahead to 2050: Scenarios of alternative investment approaches. In *Water for Food Water for Life: A Comprehensive Assessment of Water Management in Agriculture* (pp. 91-145).
de Louw, P. G. B., Oude Essink, G. H. P., Stuyfzand, P. J., & van der Zee, S. E. A. T. M. (2010). Upward groundwater flow in boils as the dominant mechanism of salinization in deep polders, The Netherlands. *Journal of Hydrology, 394*(3–4), 494-506. http://dx.doi.org/10.1016/j.jhydrol.2010.10.009
de Vente, J., Reed, M. S., Stringer, L. C., Valente, S., & Newig, J. (2016). How does the context and design of participatory decision making processes affect their outcomes? Evidence from sustainable land management in global drylands. *Ecology and society, 21*(2). https://doi.org/10.5751/ES-08053-210224
Deelstra, Y., Nooteboom, S. G., Kohlmann, H. R., Van Den Berg, J., & Innanen, S. (2003). Using knowledge for decision-making purposes in the context of large projects in The Netherlands. *Environmental Impact Assessment Review, 23*(5), 517-541. http://doi.org/10.1016/S0195-9255(03)00070-2

Derkzen, M. L., Nagendra, H., Van Teeffelen, A. J. A., Purushotham, A., & Verburg, P. H. (2017). Shifts in ecosystem services in deprived urban areas: understanding people's responses and consequences for well-being. *Ecology and society, 22*(1). http://doi.org/10.5751/ES-09168-220151

Devineni, N., Perveen, S., & Lall, U. (2013). Assessing chronic and climate-induced water risk through spatially distributed cumulative deficit measures: A new picture of water sustainability in India. *Water Resources Research, 49*(4), 2135-2145. https://doi.org/10.1002/wrcr.20184

Dewulf, A. R. P. J., & Termeer, C. J. A. M. (2015). Governing the future? The potential of adaptive delta management to contribute to governance capabilities for dealing with the wicked problem of climate change adaptation. *Journal of Water and Climate Change, 6*(4), 759-771. Retrieved from http://edepot.wur.nl/363135

Di Baldassarre, G., Brandimarte, L., & Beven, K. (2016). The seventh facet of uncertainty: wrong assumptions, unknowns and surprises in the dynamics of human–water systems. *Hydrological Sciences Journal, 61*(9), 1748-1758. 10.1080/02626667.2015.1091460

Di Baldassarre, G., Wanders, N., AghaKouchak, A., Kuil, L., Rangecroft, S., Veldkamp, T. I. E., . . . Van Loon, A. F. (2018). Water shortages worsened by reservoir effects. *Nature Sustainability, 1*(11), 617-622. https://doi.org/10.1038/s41893-018-0159-0

Dialogue Matters. (2018). *Stakeholder Dialogue: A good practice approach to participation, version 4*. Retrieved from Wye, UK: https://dialoguematters.co.uk/resource-library/

Dijksterhuis, A. (2007). *Het slimme onbewuste: denken met gevoel*. Amsterdam, the Netherlands: Bert Bakker.

Dillon, C. R. (1993). Advanced breakeven analysis of agricultural enterprise budgets. *Agricultural Economics, 9*(2), 127-143. http://dx.doi.org/10.1016/0169-5150(93)90008-Z

Dore, J. (2014). An agenda for deliberative water governance arenas in the Mekong. *Water Policy, 16*(S2), 194-214. https://doi.org/10.2166/wp.2014.204

Dore, M. H. I. (2005). Climate change and changes in global precipitation patterns: What do we know? *Environment International, 31*(8), 1167-1181. https://doi.org/10.1016/j.envint.2005.03.004

DPIPWE. (2017). *Growing Tasmanian Agriculture, Research, Development and Extension for 2050*. Retrieved from Hobart, Australia:

Dryzek, J. S. (2006). *Deliberative global politics : discourse and democracy in a divided world*. Cambridge: Polity.

Dunn, K. (2000). Interviewing. In I. Hay (Ed.), *Qualitative Research Methods in Human Geography* (pp. 50-81). Oxford, UK: Oxford University Press.

Duvail, S., Mwakalinga, A. B., Eijkelenburg, A., Hamerlynck, O., Kindinda, K., & Majule, A. (2014). Jointly thinking the post-dam future: Exchange of local and scientific knowledge on the lakes of the Lower Rufiji, Tanzania. *Hydrological Sciences Journal, 59*(3-4), 713-730. https://doi.org/10.1080/02626667.2013.827792

Ekren, O., Ekren, B. Y., & Ozerdem, B. (2009). Break-even analysis and size optimization of a PV/wind hybrid energy conversion system with battery storage - A case study. *Applied Energy, 86*(7-8), 1043-1054. http://doi.org/10.1016/j.apenergy.2008.09.024

Ellison, J. C., Smethurst, P. J., Morrison, B. M., Keast, D., Almeida, A., Taylor, P., . . . Yu, H. (2019). Real-time river monitoring supports community management of low-flow periods. *Journal of Hydrology, 572*, 839-850. https://doi.org/10.1016/j.jhydrol.2019.03.035

Falkenmark, M. (1977). Water and Mankind: A Complex System of Mutual Interaction. *Ambio, 6*(1), 3-9. http://www.jstor.org/stable/4312233

Falkenmark, M. (1979). Main Problems of Water Use and Transfer of Technology. *GeoJournal, 3*(5), 435-443. http://www.jstor.org/stable/41142292

FAO. (2003). *Review of World Water Resources by Country*. Rome, Italy: Food and Agriculture Organization of the United Nations.

Farber, S. C., Costanza, R., & Wilson, M. A. (2002). Economic and ecological concepts for valuing ecosystem services. *Ecological Economics, 41*(3), 375-392. https://doi.org/10.1016/S0921-8009(02)00088-5

Feeny, D., Berkes, F., McCay, B. J., & Acheson, J. M. (1990). The Tragedy of the Commons: Twenty-two years later. *Human Ecology, 18*(1), 1-19. https://doi.org/10.1007/bf00889070

Flyvbjerg, B. (1998). Habermas and Foucault: Thinkers for Civil Society? *The British Journal of Sociology, 49*(2), 210-233. https://doi.org/10.2307/591310

Folke, C. (2016). Resilience (Republished). *Ecology and society, 21*(4). https://doi.org/10.5751/ES-09088-210444

Forester, J. (1999). *The deliberative practitioner: Encouraging participatory planning processes*. London, England: The MIT Press.

Fowler, K., Morden, R., Lowe, L., & Nathan, R. (2015). Advances in assessing the impact of hillside farm dams on streamflow. *Australian Journal of Water Resources, 19*(2), 96-108. https://doi.org/10.1080/13241583.2015.1116182

Frey, C. H., & Patil, S. R. (2002). Identification and Review of Sensitivity Analysis Methods. *Risk Analysis, 22*(3), 553-578. http://doi.org/10.1111/0272-4332.00039.

Gamble, R., & Hogan, T. (2019). Watersheds in watersheds: The fate of the planet's major river systems in the Great Acceleration. *Thesis Eleven, 150*(1), 3-25. https://doi.org/10.1177/0725513619826190

Garrick, D. E., Hall, J. W., Dobson, A., Damania, R., Grafton, R. Q., Hope, R., . . . Money, A. (2017). Valuing water for sustainable development. *Science, 358*(6366), 1003-1005. http://doi.org/10.1126/science.aao4942

Gerlak, A. K., Heikkila, T., Smolinski, S. L., Huitema, D., & Armitage, D. (2018). Learning our way out of environmental policy problems: a review of the scholarship. *Policy Sciences, 51*(3), 335-371. https://doi.org/10.1007/s11077-017-9278-0

Ghimire, S. R., & Johnston, J. M. (2019). Sustainability assessment of agricultural rainwater harvesting: Evaluation of alternative crop types and irrigation practices. *PLoS ONE, 14*(5). https://doi.org/10.1371/journal.pone.0216452

Gleick, P. H. (2003). Global Freshwater Resources: Soft-Path Solutions for the 21st Century. *Science, 302*(5650), 1524-1528. https://doi.org/10.1126/science.1089967

Godfrey-Wood, R. (2016, 2016-12-14). Political Challenges of Addressing Climate Change through the 'Entrepreneurial State'. *States, Markets and Society – Looking Back to Look Forward New Relationships for a New Development Era, 47(2A),* 125-137. Retrieved from http://bulletin.ids.ac.uk/idsbo/article/view/2803

Grafton, R. Q., Williams, J., Perry, C. J., Molle, F., Ringler, C., Steduto, P., . . . Allen, R. G. (2018). The paradox of irrigation efficiency. *Science, 361*(6404), 748-750. https://doi.org/10.1126/science.aat9314

Graversgaard, M., Jacobsen, B. H., Kjeldsen, C., & Dalgaard, T. (2017). Stakeholder Engagement and Knowledge Co-Creation in Water Planning: Can Public Participation Increase Cost-Effectiveness? *Water, 9*(3), 191. https://doi.org/10.3390/w9030191

Griffin, R. C. (2006). *Water Resource Economics. The Analysis of Scarcity, Policies, and Projects*. Cambridge, US: The MIT Press.

Groot, A., & Maarleveld, M. (2000). *Demystifying facilitation in participatory development*. London, UK: International Institute for Environment and Development.

Groot, A. E. (2002). *Demystifying facilitation of multi-actor learning processes.* (PhD). Wageningen University, Wageningen, the Netherlands. Retrieved from http://edepot.wur.nl/165782

Guillaume, J. H. A., Arshad, M., Jakeman, A. J., Jalava, M., & Kummu, M. (2016). Robust discrimination between uncertain management alternatives by iterative reflection on crossover point scenarios: Principles, design and implementations. *Environmental Modelling and Software, 83*, 326-343. https://doi.org/10.1016/j.envsoft.2016.04.005

Gunderson, L., & Light, S. S. (2007). Adaptive management and adaptive governance in the everglades ecosystem. *Policy Sciences, 39*(4), 323-334. https://doi.org/10.1007/s11077-006-9027-2

Haasnoot, M., Middelkoop, H., van Beek, E., & van Deursen, W. P. A. (2011). A method to develop sustainable water management strategies for an uncertain future. *Sustainable Development, 19*(6), 369-381. https://doi.org/10.1002/sd.438

Haasnoot, M., Kwakkel, J. H., Walker, W. E., & ter Maat, J. (2013). Dynamic adaptive policy pathways: A method for crafting robust decisions for a deeply uncertain world. *Global Environmental Change, 23*(2), 485-498. http://dx.doi.org/10.1016/j.gloenvcha.2012.12.006

Haasnoot, M., L. Bouwer, F. Diermanse, J. Kwadijk, A. van der Spek, G. Oude Essink, . . . E. Mosselman. (2018a). *Mogelijke gevolgen van versnelde zeespiegelstijging voor het Deltaprogramma. Een verkenning.* Retrieved from Delft, the Netherlands: https://www.deltacommissaris.nl/documenten/publicaties/2018/09/18/dp2019-b-rapport-deltares

Haasnoot, M., van 't Klooster, S., & van Alphen, J. (2018b). Designing a monitoring system to detect signals to adapt to uncertain climate change. *Global Environmental Change, 52*, 273-285. https://doi.org/10.1016/j.gloenvcha.2018.08.003

Habermas, J. (1998). *On the pragmatics of communication, Studies in contemporary German social thought*. Cambridge, US: MIT press.

Habermas, J. (2008). *Between Naturalism and Relgion, Philosophical Essays* (C. Cronin, Trans.). Cambridge, US: Polity Press.

Habets, F., Molénat, J., Carluer, N., Douez, O., & Leenhardt, D. (2018). The cumulative impacts of small reservoirs on hydrology: A review. *Science of The Total Environment, 643*, 850-867. https://doi.org/10.1016/j.scitotenv.2018.06.188

Hajer, M., & Versteeg, W. (2005). A decade of discourse analysis of environmental politics: Achievements, challenges, perspectives. *Journal of Environmental Policy & Planning, 7*(3), 175-184. https://doi.org/10.1080/15239080500339646

Harou, J. J., Pulido-Velazquez, M., Rosenberg, D. E., Medellín-Azuara, J., Lund, J. R., & Howitt, R. E. (2009). Hydro-economic models: Concepts, design, applications, and future prospects. *Journal of Hydrology, 375*(3), 627-643. https://doi.org/10.1016/j.jhydrol.2009.06.037

Hellegers, P. J. G. J., & Perry, C. J. (2006). Can Irrigation Water Use Be Guided by Market Forces? Theory and Practice. *International Journal of Water Resources Development, 22*(1), 79-86. http://dx.doi.org/10.1080/07900620500405643

Hellegers, P. J. G. J. (2006). The role of economics in irrigation water management. *Irrigation and Drainage, 55*(2), 157-163. http://doi.org/10.1002/ird.223

Hellegers, P. J. G. J., & van Halsema, G. (2019). Weighing economic values against societal needs: questioning the roles of valuing water in practice. *Water Policy, 21*(3), 514-525. https://doi.org/10.2166/wp.2019.048

Hermans, L. M., Renault, D., Emrton, L., Perrot-Maitre, D., Nguyen-Khoa, S., & Smith, L. (2006a). *Stakeholder-oriented valuation to support water resources management processes: Confronting concepts with local practice*. Rome, Italy: Food & Agriculture Organization of the United Nations.

Hermans, L. M., Van Halsema, G. E., & Mahoo, H. F. (2006b). Building a mosaic of values to support local water resources management. *Water Policy, 8*(5), 415-434. http://doi.org/10.2166/wp.2006.051

HLPW. (2018). *Making Every Drop Count, An Agenda for Water Action*. Retrieved from https://sustainabledevelopment.un.org/content/documents/17825HLPW_Outcome.pdf

Hoekstra, A. Y., Savenije, H. H. G., & Chapagain, A. K. (2001). An Integrated Approach Towards Assessing the Value of Water: A Case Study on the Zambezi Basin. *Integrated Assessment, 2*(4), 199-208. http://doi.org/10.1023/a:1013368524528

Hoogvliet, M., Stuyt, L., Bakel, J. v., Velstra, J., Louw, P. d., Massop, H., . . . Nikkels, M. J. (2014). *Methode voor het selecteren van lokale zoetwateroplossingen en het afwegen van hun effecten, Fresh Water Options Optimizer*. Retrieved from Utrecht, the Netherlands: https://edepot.wur.nl/329919

Huber, A. (2019). Hydropower in the Himalayan Hazardscape: Strategic Ignorance and the Production of Unequal Risk. *Water, 11*(3), 414. doi:10.3390/w11030414

Hughes, D. A., & Mantel, S. K. (2010). Estimating the uncertainty in simulating the impacts of small farm dams on streamflow regimes in South Africa. *Hydrological Sciences Journal, 55*(4), 578-592. https://doi.org/10.1080/02626667.2010.484903

Huitema, D., Cornelisse, C., & Ottow, B. (2010). Is the Jury Still Out? Toward Greater Insight in Policy Learning in Participatory Decision Processes—the Case of Dutch Citizens' Juries on Water Management in the Rhine Basin. *Ecology and society, 15*(1). http://www.jstor.org/stable/26268099

Hyde, K. M., & Maier, H. R. (2006). Distance-based and stochastic uncertainty analysis for multi-criteria decision analysis in Excel using Visual Basic for Applications. *Environmental Modelling and Software, 21*(12), 1695-1710. http://doi.org/10.1016/j.envsoft.2005.08.004

ICWE. (1992). *The Dublin Statement and Report of the International Conference on Water and the Environment*. Paper presented at the Development issues for the 21st century, Dublin, Ireland.

Isaacs, W. (1999). *Dialogue and the art of thinking together : a pioneering approach to communicating in business and in life* (1st ed.). New York, US: Currency.

Jasanoff, S. (2003). Technologies of Humility: Citizen Participation in Governing Science. *Minerva : A Review of Science, Learning and Policy, 41*(3), 223-244. http://doi.org/10.1023/A:1025557512320

Johannessen, Å., & Hahn, T. (2013). Social learning towards a more adaptive paradigm? Reducing flood risk in Kristianstad municipality, Sweden. *Global Environmental Change, 23*(1), 372-381. https://doi.org/10.1016/j.gloenvcha.2012.07.009

Johnston, R. J., & Russell, M. (2011). An operational structure for clarity in ecosystem service values. *Ecological Economics, 70*(12), 2243-2249. https://doi.org/10.1016/j.ecolecon.2011.07.003

Johnston, R. J., Boyle, K. J., Adamowicz, W., Bennett, J., Brouwer, R., Cameron, T. A., . . . Vossler, C. A. (2017). Contemporary Guidance for Stated Preference Studies. *Journal of the Association of Environmental and Resource Economists, 4*(2), 319-405. http://doi.org/10.1086/691697

Kahneman, D. (2011). *Thinking, fast and slow*. New York, US: Farrar, Straus and Giroux.

Kampen, J. K., & Tamas, P. (2014). Should I take this seriously? A simple checklist for calling bullshit on policy supporting research. *Quality and quantity: international journal of methodology, 48*(3), 1213-1223. https://doi.org/10.1007/s11135-013-9830-8

Kanra, B. (2012). Binary deliberation: The role of social learning in divided societies. *Journal of Public Deliberation, 8*(1), 1. Retrieved from https://www.publicdeliberation.net/jpd/vol8/iss1/art1

Kenter, J. O., Reed, M. S., & Fazey, L. (2016a). The Deliberative Value Formation model. *Ecosystem Services, 21*, 194-207. https://doi.org/10.1016/j.ecoser.2016.09.015

Kenter, J. O., Bryce, R., Christie, M., Cooper, N., Hockley, N., Irvine, K. N., . . . Watson, V. (2016b). Shared values and deliberative valuation: Future directions. *Ecosystem Services, 21*, 358-371. https://doi.org/10.1016/j.ecoser.2016.10.006

Knapp, T., Kovacs, K., Huang, Q., Henry, C., Nayga, R., Popp, J., & Dixon, B. (2018). Willingness to pay for irrigation water when groundwater is scarce. *Agricultural Water Management, 195*, 133-141. https://doi.org/10.1016/j.agwat.2017.10.013

Krol, M. S., de Vries, M. J., van Oel, P. R., & de Araújo, J. C. (2011). Sustainability of Small Reservoirs and Large Scale Water Availability Under Current Conditions and Climate Change. *Water Resources Management, 25*(12), 3017-3026. https://doi.org/10.1007/s11269-011-9787-0

Kumar, S. (2016). *Choosing boundaries for interventions: A study of environmental water management in the Murray-Darling Basin, Australia.* (PhD). Charles Sturt University, Albury, Australia.

Kwakkel, J. H., Haasnoot, M., & Walker, W. E. (2016). Comparing Robust Decision-Making and Dynamic Adaptive Policy Pathways for model-based decision support under deep uncertainty. *Environmental Modelling & Software, 86*, 168-183. https://doi.org/10.1016/j.envsoft.2016.09.017

Lane, S. N. (2014). Acting, predicting and intervening in a socio-hydrological world. *Hydrol. Earth Syst. Sci., 18*(3), 927-952. https://doi.org/10.5194/hess-18-927-2014

Lasage, R., Aerts, J. C. J. H., Verburg, P. H., & Sileshi, A. S. (2013). The role of small scale sand dams in securing water supply under climate change in Ethiopia. *Mitigation and Adaptation Strategies for Global Change, 20*(2), 317-339. https://doi.org/10.1007/s11027-013-9493-8

Lasage, R., & Verburg, P. H. (2015). Evaluation of small scale water harvesting techniques for semi-arid environments. *Journal of Arid Environments, 118*, 48-57. https://doi.org/10.1016/j.jaridenv.2015.02.019

Lawrence, J., & Haasnoot, M. (2017). What it took to catalyse uptake of dynamic adaptive pathways planning to address climate change uncertainty. *Environmental Science & Policy, 68*, 47-57. https://doi.org/10.1016/j.envsci.2016.12.003

Leeuw, F., & Vaessen, J. (2009). *Impact Evaluations and Development, NONIE Guidance on Impact Evaluation*. Retrieved from Washington, United States: http://documents.worldbank.org/curated/en/411821468313779505/Impact-evaluations-and-development-NONIE-guidance-on-impact-evaluation

Leith, P., O'Toole, K., Haward, M., & Coffey, B. (2017). *Enhancing Science Impact: Bridging Research, Policy and Practice for Sustainability*. Calyton South, Australia: CSIRO Publishing.

Leith, P., Imhof, C. G., Kumar, S., Adhikari, R., Baker, C., Cumbo, B., & Evans, K. (2019). *Aspirations for Food and Agriculture: Final Research Report and Discussion Paper for TasAgFuture*. Retrieved from Hobart, Australia: https://www.utas.edu.au/tia/research/research-projects/projects/tas-ag-future

Lejda, A., West, J., & Nelle, S. (2009). *Building regional innovation capability: The impact of irrigation in the Coal River Valley*. Retrieved from Hobart, AUS: https://eprints.utas.edu.au/10075/1/CRV_Study_27_May_09.pdf

Lemos, M. C., Arnott, J. C., Ardoin, N. M., Baja, K., Bednarek, A. T., Dewulf, A., . . . Wyborn, C. (2018). To co-produce or not to co-produce. *Nature Sustainability, 1*(12), 722-724. https://doi.org/10.1038/s41893-018-0191-0

Lems, P., Aarts, N., & van Woerkum, C. M. J. (2013). When Policy Hits the Ground. An Empirical Study of the Communication Practices of Project Managers of a Water Board in

Conversations for Collaborative Governance. *Environmental policy and governance, 23*(4), 234-246. https://doi.org/10.1002/eet.1618

Linton, J., & Budds, J. (2014). The hydrosocial cycle: Defining and mobilizing a relational-dialectical approach to water. *Geoforum, 57*, 170-180. https://doi.org/10.1016/j.geoforum.2013.10.008

Lipton, M., Litchfield, J., & Faurès, J.-M. (2003). The effects of irrigation on poverty: a framework for analysis. *Water Policy, 5*(5-6), 413-427. https://doi.org/10.2166/wp.2003.0026

Lo, A. Y. (2011). Analysis and Democracy: The Antecedents of the Deliberative Approach of Ecosystems Valuation. *Environment and Planning C: Government and Policy, 29*(6), 958-974. https://doi.org/10.1068/c1083

Love, D., van der Zaag, P., Uhlenbrook, S., & Owen, R. J. S. (2011). A water balance modelling approach to optimising the use of water resources in ephemeral sand rivers. *River Research and Applications, 27*(7), 908-925. https://doi.org/10.1002/rra.1408

LTO Netherlands. (2019). *Jaarverslag Deltaplan Agrarisch Waterbeheer 2018*. Retrieved from Den Haag, The Netherlands: https://agrarischwaterbeheer.nl/jaarverslag2018

Lumosi, C. K., Pahl-Wostl, C., & Scholz, G. (2019). Can 'learning spaces' shape transboundary management processes? Evaluating emergent social learning processes in the Zambezi basin. *Environmental Science & Policy, 97*, 67-77. https://doi.org/10.1016/j.envsci.2019.04.005

Lynch, B. D. (2019). What Hirschman's Hiding Hand Hid in San Lorenzo and Chixoy. *Water, 11*(3), 415. https://doi.org/10.3390/w11030415

Mancarella, P. (2014). MES (multi-energy systems): An overview of concepts and evaluation models. *Energy, 65*, 1-17. https://doi.org/10.1016/j.energy.2013.10.041

Masih, I., Maskey, S., Uhlenbrook, S., & Smakhtin, V. (2011). Impact of upstream changes in rain-fed agriculture on downstream flow in a semi-arid basin. *Agricultural Water Management, 100*(1), 36-45. https://doi.org/10.1016/j.agwat.2011.08.013

Masih, I. (2011). *Understanding Hydrological Variability for Improved Water Management in the Semi-Arid Karkheh Basin, Iran.* (PhD). UNESCO-IHE/TU Delft, Delft, the Netherlands. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-85059293577&partnerID=40&md5=0b1db5bc431e25f33051fa5cb25e96e9 Scopus database.

Mazur, J. E. (2000). Tradeoffs among delay, rate, and amount of reinforcement. *Behavioural Processes, 49*(1), 1-10. http://dx.doi.org/10.1016/S0376-6357(00)00070-X

McCartney, M., Rebelo, L. M., Xenarios, S., & Smakhtin, V. (2013). *Agricultural water storage in an era of climate change: Assessing need and effectiveness in Africa*. Retrieved from Colombo, Sri Lanka: iwmi.cgiar.org/publications/iwmi-research-reports/iwmi-research-report-152/

McCrum, G., Blackstock, K., Matthews, K., Rivington, M., Miller, D., & Buchan, K. (2009). Adapting to climate change in land management: the role of deliberative workshops in enhancing social learning. *Environmental policy and governance, 19*(6), 413-426. https://doi.org/10.1002/eet.525

McMillan, H., Montanari, A., Cudennec, C., Savenije, H., Kreibich, H., Krueger, T., . . . Xia, J. (2016). Panta Rhei 2013–2015: global perspectives on hydrology, society and change. *Hydrological Sciences Journal, 61*(7), 1174-1191. https://doi.org/10.1080/02626667.2016.1159308

Meinke, H., Howden, S. M., Struik, P. C., Nelson, R., Rodriguez, D., & Chapman, S. C. (2009). Adaptation science for agriculture and natural resource management—urgency and theoretical basis. *Current Opinion in Environmental Sustainability, 1*(1), 69-76. https://doi.org/10.1016/j.cosust.2009.07.007

Melsen, L. A., Vos, J., & Boelens, R. (2018). What is the role of the model in socio-hydrology? Discussion of “Prediction in a socio-hydrological world” *Hydrological Sciences Journal, 63*(9), 1435-1443. https://doi.org/10.1080/02626667.2018.1499025

Merrey, D. J. (2009). African models for transnational river basin organisations in Africa: An unexplored dimension. *Water Alternatives, 2*(2), 183-204. Retrieved from https://www.scopus.com/inward/record.uri?eid=2-s2.0-67651098933&partnerID=40&md5=5fa6a27996b2acc15ad63c80658ddc9b

Mesa-Jurado, M. A., Martin-Ortega, J., Ruto, E., & Berbel, J. (2012). The economic value of guaranteed water supply for irrigation under scarcity conditions. *Agricultural Water Management, 113*, 10-18. https://doi.org/10.1016/j.agwat.2012.06.009

Metze, T. A. P. (2010). *Innovation Ltd. Boundary work in deliberative governance in land use planning.* University of Amsterdam, Amsterdam, the Netherlands.

Ministry of Infrastructure & Environment (I&M), & Ministry of Economic Affairs (EZ). (2014). *Advies Deltaplan Zoetwater - Uitvoeringsprogramma bij de Voorkeursstrategie Zoetwater*. Retrieved from Den Haag, the Netherlands: https://www.deltacommissaris.nl/deltaprogramma/documenten/publicaties/2014/09/16/advies-deltaplan-zoetwater-2014

Ministry of Infrastructure and Water Management, Ministry of Agriculture, N., and Food Quality,, & Ministry of the Interior and Kingdom Relations. (2018). *Delta Programme 2019. Continuing the work on the delta: adapting the Netherlands to climate change in time*. Retrieved from Den Haag, Netherlands: https://english.deltacommissaris.nl/documents/publications/2018/09/18/dp2019-en-printversie

Ministry of Infrastructure and Water Management (I&M), & Ministry of Economic Affairs (EZ). (2011). *Deltaprogramma 2012 - Werk aan de delta: Maatregelen van nu, voorbereiding voor morgen*. Retrieved from Den Haag, the Netherlands: https://www.deltacommissaris.nl/deltaprogramma/documenten/publicaties/2011/09/20/deltaprogramma-2012

Ministry of Infrastructure and Water Management (I&M), & Ministry of Economic Affairs (EZ). (2014). *Een veilig en veerkrachtig IJsselmeergebied - Synthesedocument* Retrieved from Den Haag, the Netherlands: https://www.deltacommissaris.nl/deltaprogramma/documenten/publicaties/2014/09/16/deltaprogramma-2015-achtergronddocument-b5

Ministry of Infrastructure and Water Management (I&M), & Ministry of Economic Affairs (EZ). (2015). *Conceptnotitie reikwijdte en detailniveau planMER, Structuurvisie Ondergrond*. Retrieved from Den Haag, the Netherlands: https://www.rijksoverheid.nl/documenten/rapporten/2015/02/09/conceptnotitie-reikwijdte-en-detailniveau-planmer-structuurvisie-ondergrond

Mostert, E., Craps, M., & Pahl-Wostl, C. (2008). Social learning: the key to integrated water resources management? *Water International, 33*(3), 293-304. http://doi.org/10.1080/02508060802275757

Mul, M., Obuobie, E., Appoh, R., KankamYeboah, K., Bekoe-Obeng, E., Amisigo, B., . . . McCartney, M. (2015). *Water resources assessment of the Volta River Basin*. Retrieved from Colombo, Sri Lanka: https://hdl.handle.net/10568/75719

Mul, M. L., & Gao, Y. (2016). Environmental Flow Requirements in the Volta Basin. In T. O. Williams, M. L. Mul, C. Biney, & V. Smakhtin (Eds.), *The Volta River Basin. Water for Food, Economic Growth and Environment* (pp. 199-213). London, UK: Routledge.

Muro, M., & Jeffrey, P. (2008). A critical review of the theory and application of social learning in participatory natural resource management processes. *Journal of Environmental*

Planning and Management, 51(3), 325-344. https://doi.org/10.1080/09640560801977190

Musgrave, W. (2008). Historical Development of Water Resources in Australia: Irrigation in the Murray-Darling Basin. In L. Crase (Ed.), *Water Policy in Australia: The impact of change and uncertainty*. New York, US: Routledge.

Nathan, R., & Lowe, L. (2012). The Hydrologic Impacts of Farm Dams. *Australasian Journal of Water Resources, 16*(1), 75-83. https://doi.org/10.7158/13241583.2012.11465405

Nelle, S. (2010). *Building Regional Innovation Capability: The Coal River Valley Experience*. Retrieved from Hobart, Australia:

Nelson, R. A., Holzworth, D. P., Hammer, G. L., & Hayman, P. T. (2002). Infusing the use of seasonal climate forecasting into crop management practice in North East Australia using discussion support software. *Agricultural Systems, 74*(3), 393-414. https://doi.org/10.1016/S0308-521X(02)00047-1

Newig, J., Haberl, H., Pahl-Wostl, C., & Rothman, D. S. (2008). Formalised and Non-Formalised Methods in Resource Management—Knowledge and Social Learning in Participatory Processes: An Introduction. *Systemic Practice and Action Research, 21*(6), 381-387. http://doi.org/10.1007/s11213-008-9112-x

Nikkels, M. J., van Bakel, P. J. T., Delsman, J. R., de Louw, P. G. B., van Oel, P. R., Stuyt, L. C. P. M., . . . Hellegers, P. J. G. J. (2015). *The regional feasibility of augmented local water storages* Paper presented at the 21st International Congress on Modelling and Simulation, Gold Coast, Australia.

Nikkels, M. J., Oel, P. R. v., Meinke, H., & Hellegers, P. J. G. J. (2019a). Challenges in assessing the regional feasibility of local water storage. *Water International, 44*(8), 854-870. https://doi.org/10.1080/02508060.2019.1656429

Nikkels, M. J., Guillaume, J. H. A., Leith, P., Mendham, N. J., van Oel, P. R., Hellegers, P. J. G. J., & Meinke, H. (2019b). Participatory Crossover Analysis to Support Discussions about Investments in Irrigation Water Sources. *Water, 11*(7), 1318. https://doi.org/10.3390/w11071318

Nikkels, M. J., Guillaume, J. H. A., Leith, P., & Hellegers, P. J. G. J. (2019c). Sharing Reasoning Behind Individual Decisions to Invest in Joint Infrastructure. *Water, 11*(4), 798. https://doi.org/10.3390/w11040798

Nikkels, M. J., Kumar, S., & Meinke, H. (2019d). Adaptive irrigation infrastructure — linking insights from human-water interactions and adaptive pathways. *Current Opinion in Environmental Sustainability, 40*, 37-42. https://doi.org/10.1016/j.cosust.2019.09.001

Nikkels, M. J., Sommeijer, M., Klap, V., Moerman, T., & Arts, M. (2019e). Samen leren om samen beter te beheren: Een groepsgesprek over de waarde van water in de Waterhouderij Walcheren, Zeeland. *Water Governance*(01/19), 50-53. Retrieved from https://edepot.wur.nl/474176

Nikkels, M. J., Leith, P., Mendham, N., & Dewulf, A. R. P. J. (submitted). The social learning potential of participatory water valuation workshops: a case study in Tasmania, Australia.

Norman, E. S., Dunn, G., Bakker, K., Allen, D. M., & de Albuquerque, R. C. (2013). Water Security Assessment: Integrating Governance and Freshwater Indicators. *Water Resources Management, 27*(2), 535-551. https://doi.org/10.1007/s11269-012-0200-4

Offermans, A., & Valkering, P. (2016). Socially Robust River Management: Role of Perspective Dependent Acceptability Thresholds. *Journal of Water Resources Planning and Management, 142*(2), 04015062. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000615

Öhlmér, B., Olson, K., & Brehmer, B. (1998). Understanding farmers' decision making processes and improving managerial assistance. *Agricultural Economics, 18*(3), 273-290. http://doi.org/10.1016/S0169-5150(97)00052-2

Olsson, L., Jerneck, A., Thoren, H., Persson, J., & O'Byrne, D. (2015). Why resilience is unappealing to social science: Theoretical and empirical investigations of the scientific use of resilience. *Science Advances, 1*(4), e1400217. https://doi.org/10.1126/sciadv.1400217

Orchard-Webb, J., Kenter, J. O., Bryce, R., & Church, A. (2016). Deliberative Democratic Monetary Valuation to implement the Ecosystem Approach. *Ecosystem Services, 21*, 308-318. https://doi.org/10.1016/j.ecoser.2016.09.005

Ostrom, E. (1993). Design principles in long-enduring irrigation institutions. *Water Resources Research, 29*(7), 1907-1912. https://doi.org/10.1029/92wr02991

Oude Essink, G. H. P. (2001). Saltwater intrusion in 3D large-scale aquifers: A Dutch case. *Physics and Chemistry of the Earth, Part B: Hydrology, Oceans and Atmosphere, 26*(4), 337-344. https://doi.org/10.1016/S1464-1909(01)00016-8

Ouma, Y. O. (2016). Evaluation of multiresolution digital elevation model (DEM) from real-time kinematic GPS and ancillary data for reservoir storage capacity estimation. *Hydrology, 3*(2). https://doi.org/10.3390/hydrology3020016

Pahl-Wostl, C., Sendzimir, J., Jeffrey, P., Aerts, J., Berkamp, G., & Cross, K. (2007a). Managing change toward adaptive water management through social learning. *Ecology and society, 12*(2). https://doi.org/10.5751/ES-02147-120230

Pahl-Wostl, C., Craps, M., Dewulf, A., Mostert, E., Tabara, D., & Taillieu, T. (2007b). Social learning and water resources management. *Ecology and society, 12*(2). http://doi.org/10.5751/ES-02037-120205

Pahl-Wostl, C., Mostert, E., & Tàbara, D. (2008a). The growing importance of social learning in water resources management and sustainability science. *Ecology and society, 13*(1). http://doi.org/10.5751/ES-02352-130124

Pahl-Wostl, C., Tàbara, D., Bouwen, R., Craps, M., Dewulf, A., Mostert, E., . . . Taillieu, T. (2008b). The importance of social learning and culture for sustainable water management. *Ecological Economics, 64*(3), 484-495. http://dx.doi.org/10.1016/j.ecolecon.2007.08.007

Pahl-Wostl, C. (2009). A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change, 19*(3), 354-365. http://dx.doi.org/10.1016/j.gloenvcha.2009.06.001

Pahl-Wostl, C. (2017). An Evolutionary Perspective on Water Governance: From Understanding to Transformation. *Water Resources Management, 31*(10), 2917-2932. http://doi.org/10.1007/s11269-017-1727-1

Pande, S., & Sivapalan, M. (2017). Progress in socio-hydrology: a meta-analysis of challenges and opportunities. *Wiley Interdisciplinary Reviews: Water, 4*(4), e1193. https://doi.org/10.1002/wat2.1193

Pandey, P. K., Soupir, M. L., Singh, V. P., Panda, S. N., & Pandey, V. (2011). Modeling Rainwater Storage in Distributed Reservoir Systems in Humid Subtropical and Tropical Savannah Regions. *Water Resources Management, 25*(13), 3091-3111. https://doi.org/10.1007/s11269-011-9847-5

Pandey, P. K., van der Zaag, P., Soupir, M. L., & Singh, V. P. (2013). A New Model for Simulating Supplemental Irrigation and the Hydro-Economic Potential of a Rainwater Harvesting System in Humid Subtropical Climates. *Water Resources Management, 27*(8), 3145-3164. https://doi.org/10.1007/s11269-013-0340-1

Pearce, D. W., & Seccombe-Hett, T. (2000). Economic Valuation and Environmental Decision-Making in Europe. *Environmental Science & Technology, 34*(8), 1419-1425. http://doi.org/10.1021/es9906711

Post, D. A., Chiew, F. H. S., Teng, J., Viney, N. R., Ling, F. L. N., Harrington, G., . . . McLoughlin, R. (2012). A robust methodology for conducting large-scale assessments of current and future water availability and use: A case study in Tasmania, Australia. *Journal of Hydrology, 412–413*, 233-245. http://dx.doi.org/10.1016/j.jhydrol.2011.02.011

Pot, W. D., Dewulf, A., Biesbroek, G. R., Vlist, M. J. v. d., & Termeer, C. J. A. M. (2018). What makes long-term investment decisions forward looking: A framework applied to the case of Amsterdam's new sea lock. *Technological Forecasting and Social Change, 132*, 174-190. https://doi.org/10.1016/j.techfore.2018.01.031

Pretty, J., & Ward, H. (2001). Social Capital and the Environment. *World Development, 29*(2), 209-227. https://doi.org/10.1016/S0305-750X(00)00098-X

Raadgever, G. T., Mostert, E., & van de Giesen, N. C. (2012). Learning from Collaborative Research in Water Management Practice. *Water Resources Management, 26*(11), 3251-3266. http://doi.org/10.1007/s11269-012-0070-9

Ranger, N., Reeder, T., & Lowe, J. (2013). Addressing 'deep' uncertainty over long-term climate in major infrastructure projects: four innovations of the Thames Estuary 2100 Project. *EURO Journal on Decision Processes, 1*(3), 233-262. https://doi.org/10.1007/s40070-013-0014-5

Ranger, S., Kenter, J. O., Bryce, R., Cumming, G., Dapling, T., Lawes, E., & Richardson, P. B. (2016). Forming shared values in conservation management: An interpretive-deliberative-democratic approach to including community voices. *Ecosystem Services, 21*, 344-357. https://doi.org/10.1016/j.ecoser.2016.09.016

Ravalico, J. K., Dandy, G. C., & Maier, H. R. (2010). Management Option Rank Equivalence (MORE) - A new method of sensitivity analysis for decision-making. *Environmental Modelling and Software, 25*(2), 171-181. http://doi.org/10.1016/j.envsoft.2009.06.012

Raworth, K. (2017). *Doughnut economics: seven ways to think like a 21st-century economist*. London, UK: Chelsea Green Publishing.

Reed, M., Stringer, L., Fazey, I., Evely, A., & Kruijsen, J. (2014). Five principles for the practice of knowledge exchange in environmental management. *Journal of Environmental Management, 146*, 337-345. https://doi.org/10.1016/j.jenvman.2014.07.021

Reed, M. S., Evely, A., Cundill, G., Fazey, I., Glass, J., Laing, A., . . . Raymond, C. (2010). What is social learning? *Ecology and society, 15*(4). http://doi.org/10.5751/ES-03564-1504r01

Ricart, S., Rico, A., Kirk, N., Bülow, F., Ribas-Palom, A., & Pavón, D. (2019). How to improve water governance in multifunctional irrigation systems? Balancing stakeholder engagement in hydrosocial territories. *International Journal of Water Resources Development, 35*(3), 491-524. http://doi.org/10.1080/07900627.2018.1447911

Ridder, D., Mostert, E., Wolters, H. A., & HarmoniCOP Team. (2005). *Learning together to manage together; Improving participation in water management*. Osnabrück, Germany: University of Osnabrück.

Rodela, R. (2011). Social learning and natural resource management: The emergence of three research perspectives. *Ecology and society, 16*(4). http://doi.org/10.5751/ES-04554-160430

Rodela, R. (2012). Advancing the deliberative turn in natural resource management: An analysis of discourses on the use of local resources. *Journal of Environmental Management, 96*(1), 26-34. https://doi.org/10.1016/j.jenvman.2011.10.013

Rodela, R. (2013). The social learning discourse: Trends, themes and interdisciplinary influences in current research. *Environmental Science & Policy, 25*, 157-166. https://doi.org/10.1016/j.envsci.2012.09.002

Rowe, G., Horlick-Jones, T., Walls, J., Poortinga, W., & Pidgeon, N. F. (2008). Analysis of a normative framework for evaluating public engagement exercises: reliability, validity and limitations. *Public Understanding of Science, 17*(4), 419-441. http://doi.org/10.1177/0963662506075351

Rufin, P., Levers, C., Baumann, M., Jägermeyr, J., Krueger, T., Kuemmerle, T., & Hostert, P. (2018). Global-scale patterns and determinants of cropping frequency in irrigation dam command areas. *Global Environmental Change, 50*, 110-122. https://doi.org/10.1016/j.gloenvcha.2018.02.011

Saruchera, D., & Lautze, J. (2019). *Small reservoirs in Africa: a review and synthesis to strengthen future investment*. Retrieved from Colombo, Sri Lanka: http://www.iwmi.cgiar.org/publications/iwmi-working-papers/iwmi-working-paper-189/

Savenije, H. H. G., & Van der Zaag, P. (2002). Water as an economic good and demand management: Paradigms with pitfalls. *Water International, 27*(1), 98-104. https://doi.org/10.1080/02508060208686982

Savenije, H. H. G., Hoekstra, A. Y., & van der Zaag, P. (2014). Evolving water science in the Anthropocene. *Hydrol. Earth Syst. Sci., 18*(1), 319-332. http://doi.org/10.5194/hess-18-319-2014

Scharmer, C. O. (2007). *Theory U: Leading from the Future as it Emerges. The Society for Organizational Learning*. Cambridge, USA.

Schneider, F., Fry, P., Ledermann, T., & Rist, S. (2009). Social Learning Processes in Swiss Soil Protection—The 'From Farmer - To Farmer' Project. *Human Ecology, 37*(4), 475-489. http://doi.org/10.1007/s10745-009-9262-1

Scholz, G., Dewulf, A., & Pahl-Wostl, C. (2014a). An Analytical Framework of Social Learning Facilitated by Participatory Methods. *Systemic Practice and Action Research, 27*(6), 575-591. http://doi.org/10.1007/s11213-013-9310-z

Scholz, G., Pahl-Wostl, C., & Dewulf, A. (2014b, 1-5 Sept.). *An Agent-Based Model of Consensus Building.* Paper presented at the Social Simulation Conference, Barcalona, Spain.

Schooler, J. W., Ohlsson, S., & Brooks, K. (1993). Thoughts Beyond Words: When Language Overshadows Insight. *Journal of Experimental Psychology: General, 122*(2), 166-183. http://doi.org/10.1037/0096-3445.122.2.166

Siddiki, S., Kim, J., & Leach, W. D. (2017). Diversity, Trust, and Social Learning in Collaborative Governance. *Public Administration Review, 77*(6), 863-874. http://doi.org/10.1111/puar.12800

Siebenhüner, B., Rodela, R., & Ecker, F. (2016). Social learning research in ecological economics: A survey. *Environmental Science & Policy, 55*, 116-126. https://doi.org/10.1016/j.envsci.2015.09.010

Siebentritt, M., Halsey, N., & Stafford-Smith, M. (2014). Regional climate change adaptation plan for the Eyre Peninsula. *Prepared for the Eyre Peninsula Integrated Climate Change Agreement Committee*.

Sinclair, K., Rawluk, A., Kumar, S., & Curtis, A. (2017). Ways forward for resilience thinking: lessons from the field for those exploring social-ecological systems in agriculture and natural resource management. *Ecology and society, 22*(4). https://doi.org/10.5751/ES-09705-220421

Sivapalan, M., Savenije, H. H. G., & Blöschl, G. (2012). Socio-hydrology: A new science of people and water. *Hydrological Processes, 26*(8), 1270-1276. https://doi.org/10.1002/hyp.8426

Smale, R., van Vliet, B., & Spaargaren, G. (2017). When social practices meet smart grids: Flexibility, grid management, and domestic consumption in The Netherlands. *Energy Research & Social Science, 34*, 132-140. https://doi.org/10.1016/j.erss.2017.06.037

Smithson, M. (1993). Ignorance and Science : Dilemmas, Perspectives, and Prospects. *Science Communication, 15*(2), 133-156. 10.1177/107554709301500202

Sol, J., Beers, P. J., & Wals, A. E. J. (2013). Social learning in regional innovation networks: trust, commitment and reframing as emergent properties of interaction. *Journal of Cleaner Production, 49*, 35-43. https://doi.org/10.1016/j.jclepro.2012.07.041

Solomon, S., Qin, D., Manning, M., Chen, Z., Marquis, M., Averyt, K. B., . . . Miller, H. L. (2007). Contribution of working group I to the fourth assessment report of the intergovernmental panel on climate change. In: Cambridge University Press, Cambridge.

Spiller, M., Vreeburg, J. H. G., Leusbrock, I., & Zeeman, G. (2015). Flexible design in water and wastewater engineering – Definitions, literature and decision guide. *Journal of Environmental Management, 149*, 271-281. https://doi.org/10.1016/j.jenvman.2014.09.031

Srinivasan, V., Sanderson, M., Garcia, M., Konar, M., Blöschl, G., & Sivapalan, M. (2017). Prediction in a socio-hydrological world. *Hydrological Sciences Journal, 62*(3), 338-345. https://doi.org/10.1080/02626667.2016.1253844

Stringer, L., Dougill, A., Fraser, E., Hubacek, K., Prell, C., & Reed, M. (2006). Unpacking "participation" in the adaptive management of social–ecological systems: a critical review. *Ecology and society, 11*(2). http://www.ecologyandsociety.org/vol11/iss2/art39/

Šūmane, S., Kunda, I., Knickel, K., Strauss, A., Tisenkopfs, T., Rios, I. d. I., . . . Ashkenazy, A. (2018). Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. *Journal of Rural Studies, 59*, 232-241. https://doi.org/10.1016/j.jrurstud.2017.01.020

Susskind, L., & Islam, S. (2012). Water diplomacy: Creating value and building trust in transboundary water negotiations. *Science & Diplomacy, 1*(3), 1-7. http://www.sciencediplomacy.org/perspective/2012/water-diplomacy

Tasmanian Irrigation. (2012a). *An Innovation Strategy for Tasmania: Focus on Food Bowl Concept. Tranche Two Irrigation Scheme Funding Submission to Infrastructure Australia*. Retrieved from Hobart, Australia: https://www.tasmanianirrigation.com.au/source-assets/documents/news/Tasmanian_Irrigation_Infrastructure_Australia_Submission_-_August_2012_Main_Submission_-_Low_Quality.pdf

Tasmanian Irrigation. (2012b). Tasmanian Irrigation newsletter. In (October 2012, Issue 07 ed.).

Tasmanian Irrigation. (2012c). *South-East Irrigation Scheme Stage 3, Overview of Agricultural Opportunities*. Retrieved from

Tasmanian Irrigation. (2017). SE3 Irrigation District Charge rates: 2018-19. Retrieved from https://www.tasmanianirrigation.com.au/source-assets/map-data/south-east-stage-3-sorell/downloads/Annual-Charges-2018-19_SEIS3.pdf

Tasmanian Irrigation. (2019a). South East Stage 1 Irrigation Scheme. Retrieved from http://www.tasmanianirrigation.com.au/index.php/schemes/south-east-stage-1

Tasmanian Irrigation. (2019b). Recycled Water Retrieved from https://www.taswater.com.au/Customers/Recycled-Water

Tasmanian Irrigation. (2019c). South-East Stage 3 (Sorell) Irrigation Scheme. Retrieved from http://www.tasmanianirrigation.com.au/index.php/schemes/south-east-stage-3

Tasmanian Liberals. (2018). *Tranche 3 - Taking Tasmanian agriculture to the next level*. Retrieved from Hobart, Australia: https://www.tas.liberal.org.au/sites/default/files/Growing%20Agriculture.pdf

Thissen, W., Kwakkel, J., Mens, M., Sluijs, J., Stemberger, S., Wardekker, A., & Wildschut, D. (2015). Dealing with Uncertainties in Fresh Water Supply: Experiences in the Netherlands. *Water Resources Management*, 1-23. https://doi.org/10.1007/s11269-015-1198-1

Thomas, B., Steidl, J., Dietrich, O., & Lischeid, G. (2011). Measures to sustain seasonal minimum runoff in small catchments in the mid-latitudes: A review. *Journal of Hydrology, 408*(3-4), 296-307. https://doi.org/10.1016/j.jhydrol.2011.07.045

Tompkins, E. L., & Adger, W. (2004). Does adaptive management of natural resources enhance resilience to climate change? *Ecology and society, 9*(2), 10. http://www.ecologyandsociety.org/vol9/iss2/art10/

Tschirhart, C., Mistry, J., Berardi, A., Bignante, E., Simpson, M., Haynes, L., . . . Jafferally, D. (2016). Learning from one another: Evaluating the impact of horizontal knowledge exchange for environmental management and governance. *Ecology and society, 21*(2). http://doi.org/10.5751/ES-08495-210241

Turner, K., Georgiou, S., Clark, R., Brouwe, R., & Burke, J. (2004). *Economic valuation of water resources in agriculture : from the sectoral to a functional perspective of natural resource management* (Vol. 27). Rome, Italy: Food & Agriculture Organization of the United Nations.

Turning Technologies. (2019). TurningPoint. Retrieved from https://www.turningtechnologies.com/

Turral, H., Svendsen, M., & Faures, J. M. (2010). Investing in irrigation: Reviewing the past and looking to the future. *Agricultural Water Management, 97*(4), 551-560. http://dx.doi.org/10.1016/j.agwat.2009.07.012

UN Water. (2018). *Sustainable Development Goal 6 Synthesis Report 2018 on Water and Sanitation*. Retrieved from New York, US:

United Nations. (2015). *Transforming our world: The 2030 agenda for sustainable development*. Retrieved from New York, US:

United Nations. (2018). *SDG 6 Synthesis Report 2018 on Water and Sanitation*. New York, US.

Urquhart, C., Lehmann, H., & Myers, M. D. (2010). Putting the 'theory' back into grounded theory: guidelines for grounded theory studies in information systems. *Information Systems Journal, 20*(4), 357-381. http://doi.org/doi:10.1111/j.1365-2575.2009.00328.x

Van Alphen, J. (2016). The Delta Programme and updated flood risk management policies in the Netherlands. *Journal of Flood Risk Management, 9*(4), 310-319. https://doi.org/10.1111/jfr3.12183

van Asselt, M. B. A., & Rotmans, J. (2002). Uncertainty in Integrated Assessment Modelling. *Climatic Change, 54*(1), 75-105. https://doi.org/10.1023/a:1015783803445

van Bakel, P. J. T., Blom, M., Hermans, C. M. L., Paulissen, M. P. C. P., Rooij, S. A. M. v., Steingröver, E. G., . . . Verbout, A. (2008). *Klimaateffectschetsboek Noord-Holland*. Retrieved from Wageningen, the Netherlands: https://edepot.wur.nl/2579

Van Bommel, S., Röling, N., Aarts, N., & Turnhout, E. (2009). Social learning for solving complex problems: a promising solution or wishful thinking? A case study of multi-actor negotiation for the integrated management and sustainable use of the Drentsche Aa area in the Netherlands. *Environmental policy and governance, 19*(6), 400-412. https://doi.org/10.1002/eet.526

van de Craats, D., Nikkels, M. J., & Stuyt, L. (2016). Ontzilting; een oplossing voor verzilting in de vollegronds landbouw? *H20 vakartikelen.* Retrieved from https://www.h2owaternetwerk.nl/vakartikelen/ontzilting-een-oplossing-voor-verzilting-in-de-vollegronds-landbouw

van der Wal, M., De Kraker, J., Offermans, A., Kroeze, C., Kirschner, P. A., & van Ittersum, M. (2014). Measuring Social Learning in Participatory Approaches to Natural Resource Management. *Environmental policy and governance, 24*(1), 1-15. https://doi.org/10.1002/eet.1627

van der Zaag, P., & Gupta, J. (2008). Scale issues in the governance of water storage projects. *Water Resources Research, 44*(10), 1-14. https://doi.org/10.1029/2007WR006364 van Duinen, R., Filatova, T., Geurts, P., & van der Veen, A. (2015). Empirical Analysis of Farmers' Drought Risk Perception: Objective Factors, Personal Circumstances, and Social Influence. *Risk Analysis, 35*(4), 741-755. https://doi.org/10.1111/risa.12299

van Duinen, R., Filatova, T., Jager, W., & van der Veen, A. (2016). Going beyond perfect rationality: drought risk, economic choices and the influence of social networks. *Annals of Regional Science, 57*(2-3), 335–369. https://doi.org/10.1007/s00168-015-0699-4

van Halsema, G. E., & Vincent, L. (2012). Efficiency and productivity terms for water management: A matter of contextual relativism versus general absolutism. *Agricultural Water Management, 108*, 9-15. https://doi.org/10.1016/j.agwat.2011.05.016

Van Meter, K. J., Steiff, M., McLaughlin, D. L., & Basu, N. B. (2016). The socioecohydrology of rainwater harvesting in India: Understanding water storage and release dynamics across spatial scales. *Hydrology and Earth System Sciences, 20*(7), 2629-2647. https://doi.org/10.5194/hess-20-2629-2016

van Oel, P. R., Krol, M. S., & Hoekstra, A. Y. (2011). Downstreamness: A concept to analyze basin closure. *Journal of Water Resources Planning and Management, 137*(5), 404-411. https://doi.org/10.1061/(ASCE)WR.1943-5452.0000127

van Oel, P. R., Martins, E. S. P. R., Costa, A. C., Wanders, N., & van Lanen, H. A. J. (2018). Diagnosing drought using the downstreamness concept: the effect of reservoir networks on drought evolution. *Hydrological Sciences Journal, 63*(7), 979-990. https://doi.org/10.1080/02626667.2018.1470632

Vanclay, F. (2004). Social principles for agricultural extension to assist in the promotion of natural resource management. *Australian journal of experimental agriculture*(44), 213-222. https://doi.org/10.1071/EA02139

Venkatachalam, L. (2004). The contingent valuation method: a review. *Environmental Impact Assessment Review, 24*(1), 89-124. https://doi.org/10.1016/S0195-9255(03)00138-0

Veraart, J. A., van Duinen, R., & Vreke, J. (2017). Evaluation of Socio-Economic Factors that Determine Adoption of Climate Compatible Freshwater Supply Measures at Farm Level: a Case Study in the Southwest Netherlands. *Water Resources Management, 31*(2), 587-608. https://doi.org/10.1007/s11269-016-1399-2

Voinov, A., Kolagani, N., McCall, M. K., Glynn, P. D., Kragt, M. E., Ostermann, F. O., . . . Ramu, P. (2016). Modelling with stakeholders - Next generation. *Environmental Modelling and Software, 77*, 196-220. http://doi.org/10.1016/j.envsoft.2015.11.016

Walker, W. E., Haasnoot, M., & Kwakkel, J. H. (2013). Adapt or Perish: A Review of Planning Approaches for Adaptation under Deep Uncertainty. *Sustainability, 5*(3), 955. Retrieved from http://www.mdpi.com/2071-1050/5/3/955

Walton, B. (2018). Cape Town's Harrowing Journey to the Brink of Water Catastrophe. Retrieved from https://www.circleofblue.org/2018/world/cape-towns-harrowing-journey-to-the-brink-of-water-catastrophe/

Ward, F. A. (2010). Financing Irrigation Water Management and Infrastructure: A Review *International Journal of Water Resources Development, 26*(3), 321-349. https://doi.org/10.1080/07900627.2010.489308

WCD. (2000). *Dams and Development: A New Framework for Decision-making: the Report of the World Commission on Dams*. London, United Kingdom: Earthscan.

Webber, L. M., & Ison, R. L. (1995). Participatory Rural Appraisal Design: Conceptual and process issues. *Agricultural Systems, 47*(1), 107-131. https://doi.org/10.1016/0308-521X(94)P3278-3

Wehn, U., Collins, K., Anema, K., Basco-Carrera, L., & Lerebours, A. (2018). Stakeholder engagement in water governance as social learning: lessons from practice. *Water International, 43*(1), 34-59. https://doi.org/10.1080/02508060.2018.1403083

Wei, J., Wei, Y., & Western, A. (2017). Evolution of the societal value of water resources for economic development versus environmental sustainability in Australia from 1843 to 2011. *Global Environmental Change, 42*, 82-92. https://doi.org/10.1016/j.gloenvcha.2016.12.005

Wenger, E. (1998). *Communities of Practice: Learning, Meaning, and Identity*. Cambridge, UK: Cambridge University Press.

Wesselink, A., Kooy, M., & Warner, J. (2017). Socio-hydrology and hydrosocial analysis: toward dialogues across disciplines. *Wiley Interdisciplinary Reviews: Water, 4*(2), e1196. https://doi.org/10.1002/wat2.1196

Wilson, T. D., & Schooler, J. W. (1991). Thinking Too Much: Introspection Can Reduce the Quality of Preferences and Decisions. *Journal of Personality and Social Psychology, 60*(2), 181-192. http://dx.doi.org/10.1037/0022-3514.60.2.181

Wise, R. M., Fazey, I., Stafford Smith, M., Park, S. E., Eakin, H. C., Archer Van Garderen, E. R. M., & Campbell, B. (2014). Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change, 28*, 325-336. https://doi.org/10.1016/j.gloenvcha.2013.12.002

Wisser, D., Frolking, S., Douglas, E. M., Fekete, B. M., Schumann, A. H., & Vörösmarty, C. J. (2010). The significance of local water resources captured in small reservoirs for crop production–A global-scale analysis. *Journal of Hydrology, 384*(3), 264-275. https://doi.org/10.1016/j.jhydrol.2009.07.032

WOCAT. (2007). *Where the land is greener: Case studies and analysis of soil and water conservation initiatives worldwide*. Wageningen, Netherlands: CTA; FAO; UNEP; CDE.

Working Group 2.9. (2003). *Common Implementation Strategy for the Water Framework Directive (2000/60/EC), Guidance document n.o 8, Public Participation in relation to the Water Framework Directive*. Retrieved from Luxembourg, Luxembourg: https://ec.europa.eu/environment/water/water-framework/objectives/pdf/strategy2.pdf

World Bank. (2017). Charting a path to valuing the world's most precious resource. Retrieved from https://nl4worldbank.org/2017/02/17/charting-a-path-to-valuing-the-worlds-most-precious-resource/

Wutich, A., White, A. C., White, D. D., Larson, K. L., Brewis, A., & Roberts, C. (2014). Hard paths, soft paths or no paths? Cross-cultural perceptions of water solutions. *Hydrology and Earth System Sciences, 18*(1), 109-120. https://doi.org/10.5194/hess-18-109-2014

WWAP (World Water Assessment Programme). (2012). *The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk*. Retrieved from Paris, France: http://www.unesco.org/new/fileadmin/MULTIMEDIA/HQ/SC/pdf/WWDR4%20Volume%201-Managing%20Water%20under%20Uncertainty%20and%20Risk.pdf

Young, R. A., & Loomis, J. B. (2014). *Determining the economic value of water: concepts and methods* [1 online resource (359 pages) : illustrations, tables](Second edition. ed.). Retrieved from http://site.ebrary.com/id/10884828

Ziolkowska, J. R. (2015). Shadow price of water for irrigation—A case of the High Plains. *Agricultural Water Management, 153*, 20-31. https://doi.org/10.1016/j.agwat.2015.01.024

ZON & DHZ. (2015). *Wel goed water geven, werkprogramma zoetwatervoorziening hoge landgronden*. Retrieved from Wageningen, the Netherlands: https://www.zoetwatervoorzieningoostnederland.nl/zon/documenten/

Zuo, A., Wheeler, S. A., Boxall, P., Adamowicz, W. L., & MacDonald, D. H. (2015). Identifying Water Prices at which Australian Farmers Will Exit Irrigation: Results of a Stated

Preference Survey. *Economic Record, 91*(S1), 109-123. http://doi.org/10.1111/1475-4932.12186

Zuurbier, K. G., Raat, K. J., Paalman, M., Oosterhof, A. T., & Stuyfzand, P. J. (2016). How Subsurface Water Technologies (SWT) can Provide Robust, Effective, and Cost-Efficient Solutions for Freshwater Management in Coastal Zones. *Water Resources Management*, 1-17. https://doi.org/10.1007/s11269-016-1294-x

Zuurbier, K. G., Raat, K. J., Paalman, M., Oosterhof, A. T., & Stuyfzand, P. J. (2017). How Subsurface Water Technologies (SWT) can Provide Robust, Effective, and Cost-Efficient Solutions for Freshwater Management in Coastal Zones. *Water Resources Management, 31*(2), 671-687. https://doi.org/10.1007/s11269-016-1294-x

Zwarteveen, M. Z., & Boelens, R. (2014). Defining, researching and struggling for water justice: some conceptual building blocks for research and action. *Water International, 39*(2), 143-158. https://doi.org/10.1080/02508060.2014.891168

LIST OF PUBLICATIONS

Peer-reviewed articles

Nikkels, M. J., van Oel, P. R., Meinke, H., & Hellegers, P. J. G. J. (2019). Challenges in assessing the regional feasibility of local water storage. *Water International*, 44(8), 854-870.

Nikkels, M. J., Guillaume, J. H. A., Leith, P., Mendham, N. J., van Oel, P. R., Hellegers, P. J. G. J., & Meinke, H. (2019). Participatory Crossover Analysis to Support Discussions about Investments in Irrigation Water Sources. *Water*, 11(7), 1318.

Nikkels, M. J., Guillaume, J. H. A., Leith, P., & Hellegers, P. J. G. J. (2019). Sharing Reasoning Behind Individual Decisions to Invest in Joint Infrastructure. *Wate*r, 11(4), 798.

Nikkels, M. J., Kumar, S., & Meinke, H. (2019). Adaptive irrigation infrastructure — linking insights from human-water interactions and adaptive pathways. *Current Opinion in Environmental Sustainability*, 40, 37-42.

Nikkels, M. J., Leith, P., Mendham, N. J., & Dewulf, A. (submitted). The social learning potential of participatory water valuation workshops: a case study in Tasmania, Australia.

Conference papers

Nikkels, M. J., van Bakel, P. J. T., Delsman, J. R., de Louw, P. G. B., van Oel, P. R., Stuyt, L. C. P. M., Stuyt, L.C.P.M., Vellinga, P., Velstra, J., & Hellegers, P. J. G. J. (2015). The regional feasibility of augmented local water storages Paper presented at the 21st International Congress on Modelling and Simulation, Gold Coast, Australia.

Nikkels, M. J., Guillaume, J. H. A., Leith, P., Mendham, N. J., van Oel, P. R., & Meinke, H. (2017). Using crossover analysis to support water user discussion about investments in water sources for irrigation. *European Water* (60), 17-23.

Nikkels, M. J., & Leith, P. (2018). Learning about water for irrigation, a case study in Tasmania. Paper presented at the Ozwater '18 conference, Brisbane, Australia.

Peer reviewed trade journal articles

van de Craats, D., Nikkels, M. J., & Stuyt, L. (2016). Ontzilting; een oplossing voor verzilting in de vollegronds landbouw? *H20 vakartikelen.* https://www.h2owaternetwerk.nl/vakartikelen/ontzilting-een-oplossing-voor-verzilting-in-de-vollegronds-landbouw

Nikkels, M. J., Sommeijer, M., Klap, V., Moerman, T., & Arts, M. (2019). Samen leren om samen beter te beheren: Een groepsgesprek over de waarde van water in de Waterhouderij Walcheren, Zeeland. *Water Governance* (01/19), 50-53.

Other

Use of CapDI to partial desalinize brackish water for agriculture, YouTube, 11 Oct, 2016 https://www.youtube.com/watch?v=AcPqs_Oh-NI

Dutch research into Tasmanian irrigators, ABC radio, 11 Apr 2018 http://www.abc.net.au/radio/programs/tas-country-hour/dutch-irrigation-researchers/9641380

Water infrastructure: dammed if you don't, Launceston Examiner, 31 Jan 2019 https://www.Examiner-Advocate-Dammed-if-you-dont-310119.pdf

Managing water for future farming, Tasmanian Country, 8 Feb 2019 https://www.aequator.nl/wp-content/uploads/2019/02/Article-Tasmanian-Water-management.pdf

Waarom investeert een boer (niet) in waterbeheer, Resource, 21 May 2019 https://resource.wur.nl/nl/show/Waarom-investeert-een-boer-niet-in-waterbeheer-.htm

Praat met boer, hij wil best wel, Trouw, 30 Dec 2019
https://www.trouw.nl/economie/wat-wil-de-boer-nou-eigenlijk-vijf-inzichten-om-de-boerenprotesten-beter-te-snappen~bd9682dd/

Landbouw is boeren en boeren zijn (net) mensen, Foodlog, 27 Jan 2020
https://www.foodlog.nl/artikel/landbouw-is-boeren-en-boeren-zijn-net-mensen/

PhD Podcasts, PhD proat met Melle en Manne. The podcasts can be found by scanning the QR code at the beginning of each corresponding chapter and can be found on the major podcast platforms, such as Spotify, Google podcast, Apple podcast and anchor.fm. https://anchor.fm/phd-proat-met-melle-en-manne

SUMMARY

Farmers are increasingly being called upon to help manage, invest and steer water systems towards a desirable state: farmers as water managers. Through on-farm soil and water management and investment decisions, farmers influence their own water availability but their local interventions also have system-level implications. Farmers influence water systems and are in turn influenced by the water system in which they operate. System-level implications of farmers as water managers are poorly understood. This thesis explores approaches and provides insights for a better understanding of the ways in which farmers can contribute to achieving system-level objectives, such as agricultural intensification and freshwater retention capacity.

This thesis starts by examining main challenges in assessing the regional impacts of local water storage. By systematically reviewing literature on local water storage, Chapter 2 identifies and discusses technical and socio-economic difficulties encountered in assessing the regional impacts of local interventions. It concludes that the focus of assessments must shift from storage 'potential' to storage 'feasibility'. Feasibility is context specific and influenced by the spatial and temporal scales of analysis. The chapter then further explores farmers' prefercens and personal motivations for investing (or not investing) in additional water for irrigation.

Chapters 3 and 4 present, apply, and evaluate a new framework that uses 'crossover points' to support dialogue on irrigation investments in case studies in Tasmania, Australia. The framework extends the use of crossover points in a novel way to facilitate dialogue in a participatory setting, termed 'participatory crossover analysis'. Participatory crossover analysis proved to perform well as a tool for valuation of irrigation water and to foster social learning. Chapters 3 and 4 investigate farmers' personal and evolving perspectives on a) their water demand; b) the value of a reliable source of high quality water; and c) their willingness to pay for water. Their personal preferences and reasonings turned out to be diverse and broader than just short-term economic gains. Lifestyle choices, long-term intergenerational planning, perceived

risks, and intrinsic motivations were mentioned as factors influencing investment decisions. This has strong implications for the type of information that farmers considered relevant in supporting their decisions on water investments. In short, information and knowledge exchange was highly valued, particularly learning from and with peers.

Chapter 5 presents an assessment of social learning during a valuation workshop, using participatory crossover analysis as a tool to facilitate a deliberative dialogue between irrigators, scheme managers, and policymakers about the past, present, and future value of irrigation water. In the case under study, discussions between workshop participants led to new insights on the value of water, identification of potential improvements in management and governance, and cultivated a greater appreciation of the diverse perspectives in the room. These findings suggest that a single workshop can foster social learning.

Findings from the Tasmanian cases highlight that the rollout of new irrigation infrastructure triggers social change that is currently not accounted for in the design and management of irrigation schemes. New irrigation schemes are built to operate in a future that cannot be predicted. Conclusions from the cases suggest that management of water systems should be approached as an ongoing process of social learning with stakeholders. Chapter 6 offers a way forward, suggesting an approach to irrigation infrastructure that links insights from the literature on human-water interactions with insights on adaptive pathways. Adaptive approaches to water management better allow farmers to be water managers, today and in the unfolding future.

SAMENVATTING

Er wordt steeds vaker een beroep gedaan op boeren om watersystemen te helpen beheren, te (co-)investeren en te sturen naar een wenselijke toestand: boeren als waterbeheerders. Door bodem- en waterbeheer en investeringsbeslissingen op de boerderij beïnvloeden boeren hun eigen waterbeschikbaarheid, maar hun lokale interventies hebben ook implicaties op systeemniveau. Boeren beïnvloeden watersystemen en worden op hun beurt beïnvloed door het (water)systeem waarin ze opereren. De regionale implicaties van boeren als waterbeheerders zijn nog onvoldoende begrepen. Dit proefschrift biedt methoden en inzichten voor een beter begrip van de manieren waarop boeren kunnen bijdragen aan het bereiken van lange termijn doelstellingen, zoals een hoogproductieve landbouwsector (Tasmanië) of een klimaat robuust landschap (Nederland).

Dit proefschrift begint met het onderzoeken van de belangrijkste uitdagingen bij het beoordelen van de regionale effecten van lokale waterberging. Door systematisch literatuur over lokale waterberging te herzien, identificeert en bespreekt hoofdstuk 2 de technische en sociaaleconomische uitdagingen die men tegenkomt bij het beoordelen van de regionale effecten van lokale interventies. De uitdagingen worden geïllustreerd door een casus in Noord-Holland, Nederland. De conclusie luidt dat de focus van beoordelingen moet verschuiven van opslag "potentieel" naar de rol die lokale opslag kan spelen om periodes van droogte te overbruggen. Deze rol, gedefinieerd als bruikbaarheid, is context specifiek en wordt beïnvloed door de ruimtelijke en temporele schaal van analyse. Vervolgens gaat het hoofdstuk dieper in op de persoonlijke voorkeuren en redeneringen van boeren om te investeren (of niet te investeren) in extra water voor irrigatie.

Hoofdstukken 3 en 4 presenteren een nieuwe methode die "crossover-punten" gebruikt om de dialoog over irrigatie-investeringen te ondersteunen. Deze methode breidt het gebruik van crossover-punten uit naar een nieuwe manier om dialoog te ondersteunen, genaamd "participatieve crossover-analyse". Participatieve crossover-

analyse is toegepast en geëvalueerd in twee casussen in Tasmanië, Australië en bleek goed te presteren als een instrument voor het bespreken van de waarde van water en om sociaal leren te bevorderen. Hoofdstukken 3 en 4 onderzoeken de persoonlijke en veranderende perspectieven van boeren op a) hun watervraag; b) de waarde van een betrouwbare bron van water van hoge kwaliteit; en c) hun bereidheid om voor water te betalen. Hun persoonlijke redeneringen bleken divers en breder dan alleen economische winst maximalisatie op korte termijn. Levensstijlkeuzes, intergenerationele planning op lange termijn, risico's en intrinsieke motivaties werden genoemd als factoren die investeringsbeslissingen beïnvloeden. Dit heeft grote gevolgen voor de informatie die boeren relevant achten ter ondersteuning van hun investeringsbeslissingen. Kortom, informatie- en kennisuitwisseling werd relevant en waardevol gevonden, vooral het leren van en met andere boeren.

Hoofdstuk 5 presenteert een evaluatie van sociaal leren door middel van een water waarderingsworkshop. Tijdens de workshop werd gebruik gemaakt participatieve crossover-analyse als hulpmiddel om een deliberatieve dialoog tussen boeren, beheerders en beleidsmakers over de vroegere, huidige en toekomstige waarde van irrigatiewater te faciliteren. In de onderzochte casus leidden de discussies tussen deelnemers tot nieuwe inzichten over de waarde van water, identificatie van mogelijke verbeteringen in beheer en bestuur, en een grotere waardering voor de diversiteit in perspectieven en voorkeuren. Deze bevindingen suggereren dat één workshop al sociaal leren bevordert.

De bevindingen uit de Tasmaanse casussen tonen aan dat de uitrol van nieuwe irrigatie-infrastructuur sociale veranderingen teweegbrengt die momenteel niet worden meegenomen in het ontwerp en beheer van irrigatieschema's. Nieuwe irrigatieschema's zijn gebouwd om te opereren in een toekomst die niet kan worden voorspeld. Conclusies uit de casussen suggereren dat het beheer van watersystemen moet worden benaderd als een continu proces van sociaal leren met belanghebbenden. Hoofdstuk 6 biedt een weg vooruit en suggereert een benadering van irrigatie-infrastructuur die inzichten uit de literatuur over mens-waterinteracties koppelt aan inzichten over adaptieve paden. Adaptieve benaderingen van waterbeheer stellen boeren beter in staat om waterbeheerders te zijn, vandaag en in de toekomst.

Liever luisteren?

Om op een toegankelijke manier meer te weten te komen over dit onderzoek, kun je luisteren naar de podcastserie “PhD proat met Melle en Manne”. In deze podcastserie bespreken we informeel elk hoofdstuk in 15 tot 30 minuten. De podcasts zijn te vinden op Spotify, door de QR-code aan het begin van elk hoofdstuk te scannen met je telefoon en door op de volgende link te klikken https://anchor.fm/phd-proat-met-melle-en-manne.

ACKNOWLEDGEMENTS

I owe most to the farmers, water managers and policy makers that participated in this research process. By far, I learned most from and with you and it has been a great pleasure to work with such experts. I would especially like to thank all members of the Coal River Product Association for being extremely generous with your time and knowledge. In particular, I thank Peter Rand, in his role at Tasmanian Irrigation, providing in depth irrigation scheme information but also for his welcoming kindness, and his Australian humour.

Next, I thank my colourful team of supervisors. I know I have not always been the easiest PhD candidate. On the one hand, I had a strong desire to explore sort of independently and on the other hand, I could not do without your input, guidance and support. It has been an insightful journey. Thank you Petra for being there from the start and for letting me go out and discover. You did more than helping me through my PhD: the cheers and water bottles I got from you and your family made me finish the bike race on the Wageningse “mountain”. Thank you Holger for your insights on the role that scientists can/should play in society and for the many reflection sessions. Pieter, thanks for your detailed feedback and your insights on scale issues. Peat, thanks for introducing me into the social sciences, including reflexivity and boundary objects. You have been a great co-facilitator of the workshops. Then, last but not least, Neville: I am so thankful that we crossed paths. You have been irreplaceable in this journey. Your contacts in the Coal River Valley, your willingness to supervise me – even after being retired – and your kind support mean “the lot” to me.

Besides this great supervisory team, I worked with others as well. Joseph, we met just before I started by PhD. This thesis builds on your work and insights. The week I spend with you in Helsinki has been crucial. I really enjoyed our collaborative thinking sessions on participatory crossover analysis and I have learned a lot from how you put ideas on paper. Deepa, it is great to have such a good friend as a colleague. You are so wise, honest and kind. I really enjoyed writing Chapter 6 together. Art, thank you so much for helping me on social learning. It turned out to my favourite Chapter (5). Lodewijk, CEO of Fource (see text box 2.1), thank you for letting me be the Operational Manager. Theo, thank you very much for all your help making Fource ready for field tests. I admire your pioneering skills.

I also want to thank all my colleagues at Aequator for your unconditional support and the interest you showed over the years. Peter and Ruud; taking me on board shows entrepreneurship and I respect your integrity and passion for the agricultural sector. Jouke, thanks for our daily bike commute adventures, even in the snow. My dear PhD friends at the WUR; thank you for sharing your journeys with me. I learned so much from you! The colleagues at the Water Resources Management group, especially my roomies over the years, including Pieter, Arjen, Jaime, Alex, Matthijs and Gerlo, thanks for both your chats and deep conversations. I also want to thank my colleagues at UTAS for your support when I rocked up when summer came. I think weekly morning tea with home baked goods is something we should do in the Netherlands as well.

This thesis is the outcome of a great journey that took me to the other side of the world. In this journey I met a lot of people that turned into friends. Emma, you literally turned my life around and I am forever grateful for that. Andrew, I would have never imagined that lending your bike would be the start of so many adventures. Chris, my older brother: our tour of Tassie meant a lot to both of us. Midnight swimming and smelling roses changed for ever. The Running Edge boys, thanks for letting me into your brotherhood. I enjoyed the banter, the coffees and almost every kilometre we rode together. Anna, Ben, Poppy, Ruby and Issy, thank you for being my Aussie family. You are the main reason why I now feel so connected with Tasmania. Fair dinkum.

In addition to the new connections I made, I am lucky to be surrounded by family and friends. This journey was intense at times and especially in retrospect, the PhD was often more than just work. Having supporting family and friends meant more in this journey than I would have imaged when I started. Thank you for your bike rides, runs, fires, beers, coffees, discussions, questions, insights, hugs and love. Moeke, I think that you are and will be the only non-scientist that red this thesis from A-Z, thank you for your feedback on the content and your advice on the process. Manne, thank you for co-hosting our podcast and Boes, thanks for being such a loyal fan. Matthijs and Nick, thanks for being my paranymphs. Marthe, thank you for being you: *The road ahead is empty, no stop signs, speed limits, so no retreat, no surrender. Let's follow the sun* ☺

ABOUT THE AUTHOR

Melle Jochem Nikkels was born in Zuidwolde, Drenthe where he developed interest in farming and tractors. After completing the Waldorf School in Groningen in 2007, he moved to Wageningen to pursue his Bachelor International Land and Water Management, with a minor in Sustainable Forestry Management at the University of British Columbia. He then worked at Whistler Heli-skiing and at Roelofs Advies & Design.

Melle moved to Amsterdam in 2012 to obtain a Master Earth Science and Economics (Cum Laude). During the last year of his master's, he was accepted to the SENSE Honours Program of the Research School for Socio-Economic and Natural Sciences of the Environment (SENSE) to write a PhD proposal.

With this proposal, Melle started as a PhD candidate and advisor at Aequator Groen & Ruimte in 2015. His PhD contained collaboration with the Water Resources Management Group at the Wageningen University and the Tasmanian Institute of Agriculture, University of Tasmania. Melle's research focuses on agricultural water management, with the aim of contributing to a better understanding on how farmers can help reaching system level objectives. His interests are in participative approaches to water valuation and social learning.

When not behind a desk, he is outside, where he can be encountered riding one of his bikes in odd places.

Netherlands Research School for the
Socio-Economic and Natural Sciences of the Environment

DIPLOMA

for specialised PhD training

The Netherlands research school for the
Socio-Economic and Natural Sciences of the Environment
(SENSE) declares that

Melle Jochem Nikkels

born on 21 June 1989 in Zuidwolde, The Netherlands

has successfully fulfilled all requirements of the
educational PhD programme of SENSE.

Wageningen, 20 May 2020

The Chairman of the SENSE board	the SENSE Director of Education
Prof. dr. Martin Wassen	Dr. Ad van Dommelen

The SENSE Research School has been accredited by the Royal Netherlands Academy of Arts and Sciences (KNAW)

KONINKLIJKE NEDERLANDSE
AKADEMIE VAN WETENSCHAPPEN

The SENSE Research School declares that **Melle Jochem Nikkels** has successfully fulfilled all requirements of the educational PhD programme of SENSE with a work load of 50.0 EC, including the following activities:

SENSE PhD Courses

- Environmental research in context (2015)
- Research in context activity: 'Initiating and realizing PhD podcasts on the relevance and context of PhD research (published in dissertation and available on Spotify)' (2018-2019)

Other PhD and Advanced MSc Courses

- Systematic literature review, Wageningen Graduate School (2016)
- Teaching and supervising thesis students, Wageningen Graduate School (2017)
- Reviewing a scientific paper, Wageningen Graduate School (2018)

External training at a foreign research institute

- Lean Scientist, Kimate-KIC, Netherlands (2015)
- Stakeholder facilitation course, Dialogue Matters, United Kingdom (2018)

Management and Didactic Skills Training

- Supervising MSc student with thesis entitled 'Modelling the applicability of Fource' (2016)
- Supervising MSc student with thesis entitled 'Exploring long-term water management implications using a backcasting approach in Tasmania, Australia' (2018)
- Teaching in the BSc course 'Design in Land and Water Management 1' (2015-2016)
- Operational manager in the start-up Fource (2015-2017)
- Advisor Aequator Groen & Ruimte (2015-2019)
- Organising a symposium on water valuation (2019)

Oral Presentations

- *Applying the fresh water options optimizer method to assess the regional feasibility of local measures that increase water availability*. MODSIM 2015, 29 November-4 December 2015, Goldcoast, Australia
- *Using cross-over analysis to support water user discussion about investments in water sources for irrigation*. EWRA 2017, 5-9 July 2017, Athens, Greece
- *Learning about water for irrigation, a case study in Tasmania.* OzWater18, 08-10 May 2018, Brisbane, Australia
- *Expanding the conversation on irrigation system design in Tasmania.* Water for Impact 2018, 16-18 October 2018, Wageningen, The Netherlands

SENSE coordinator PhD education

Dr. ir. Peter Vermeulen

The research described in this thesis is a result of collaboration between Wageningen University, University of Tasmania and Aequator Groen & Ruimte. During this research, I was employed by Aequator Groen & Ruimte and received top-up funding, to cover operation costs, through CSIRO's Australian Sustainable Agriculture Scholarship (ASAS).

Cover Design: Fenna Schaap

Print: ProefschriftMaken

Paper: 100% recycled

Financial support from Wageningen University for printing this thesis is gratefully acknowledged.