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Reviewing the decision-making behaviour of Irrigators

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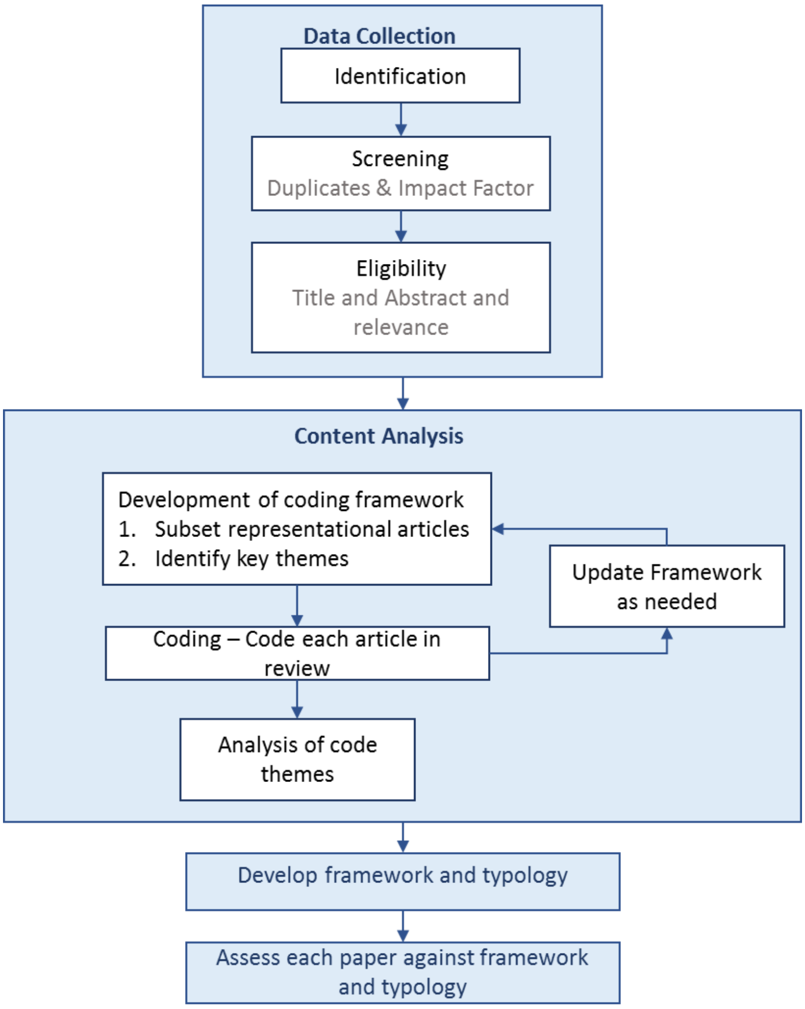
Abstract

The contribution of agriculture to society is undeniable, as is its impact on the environment. Irrigators' decisions to follow best management practices or implement a policy change, to accept a technology, or even to exit farming, all affect society. Hence the decision-making behaviour of irrigators is of interest to politicians, policy makers and researchers due to their impact on resource use and social concerns for their welfare. There are numerous studies available regarding the decision-making behaviour of irrigators. Most of them concentrate on decisions within a single time-frame, single decisions with multiple driving forces, or multiple decisions with a single driving force. We have conducted a comprehensive review of the existing literature related to irrigators' decision-making behaviour. We used a systematic method to identify relevant publications and used qualitative data analysis (Content Analysis) to analyse trends and/or patterns across the selected articles. This research provided a typology and an overarching high-level framework of irrigators' decision-making process irrespective of the types of decisions made. The results of the study demonstrate that it is highly beneficial to integrate both qualitative and quantitative methods in a single study to get a complete picture of irrigators' decision-making process. This allows us to ensure

that we have captured the relevant drivers of decision-making in highly dynamic and complex environments. Better knowledge of irrigators' decision-making process allows regulators to shape improved agricultural policy and increase acceptance by irrigators of technologies that allow water managers to allocate resources fairly among different stakeholders.

Graphical/Visual Abstract and Caption


Data Collection
Identification
Screening
Duplicates & Impact Factor
Eligibility
Title and Abstract and relevance
Content Analysis
Development of coding framework
1. Subset representational articles
2. Identify key themes
Update Framework as needed
Coding – Code each article in review
Analysis of code themes
Develop framework and typology
Assess each paper against framework and typology

Overview of methods used for reviewing irrigators' decision-making behaviour– A systematic method was used to identify key articles, and qualitative data analysis method was used to analyse the literature

1. Introduction

Agriculture is an essential part of many countries' economies and roughly one third of the world's population depends on agriculture as a means of income, poverty alleviation and/or food security (FAO, 2018). However, market fluctuations, technological advances, urban population growth, and climate change all put irrigators in a vulnerable situation and increase the probability that they will either adapt or leave the industry (Ban, 1999; Feola, Lerner, Jain, Montefrio, & Nicholas, 2015; Laube, Schraven, & Awo, 2012; Risbey, Kandlikar, Dowlatabadi, & Graetz, 1999). Currently, the agricultural sector is going through considerable restructuring as farm sizes grow and the total number of irrigators declines in response to adjustment pressures and growth in competing employment sectors (Gras, 2009; Peel, Berry, & Schirmer, 2016). Agricultural sector restructuring is therefore resulting in farming intensification with ramifications for sector profitability, adverse impacts on environment, overuse of resources, political power and rural community impacts.

Even though agricultural intensification is necessary to ensure food security for an increasing global population, intensification can ultimately cause overproduction which may lead to lower market prices, which in turn may incentivise irrigators to produce more crops in total to compensate (Ilbery, 1991). Higher productivity thus both contributes to climate change (via greenhouse gas emission) and at the same time increases irrigator vulnerability to climate change (extreme weather conditions) where higher levels of farming capital are exposed (Adamson & Loch, 2014; Arbuckle, Morton, & Hobbs, 2015; Jorgensen & Termansen, 2016). Where societies value agricultural producers, governments can often be called upon to act as the insurer of last resort to avoid significant widespread capital loss, and augment irrigator resilience in the face of adverse change. In the context of water policy, where reliance on expensive and site-specific efficiency projects can serve to constrain future choice sets for irrigators, and greatly increase their exposure to capital loss (Adamson, Loch, & Schwabe, 2017), a better understanding of the decision-making process and issues that irrigators use to inform that process can be of significant benefit. Thus, irrigator adoption of risk management processes, best management practices, technology adoption, engagement in policy/program offerings and/or the exit of farming altogether can affect society and influence political choices for the wider agricultural sector (Lei, Wang, Yue, Yin, & Sheng, 2014; S. A. Wheeler, Zuo, & Loch, 2018). Hence, the decision-making behaviour of irrigators can be of significant interest to politicians, agency officials, resource managers and researchers.

As a result of the broad interest in irrigator decision-making outlined above, the study of irrigator decision-making is not a new topic. Irrigators make highly complex decisions that are often site and context specific, and hence hard to generalise (Adam Loch, Bjornlund, Wheeler, & Connor, 2012). Many studies have shown that irrigators are not completely rational in their decision-making and that their decisions depend on various internal and external factors (Edwards-Jones, 2006; Willock, Deary, McGregor, et al., 1999). This suggests that there are various dimensions to the decision-making process. For example, many studies have concentrated on decisions within a single time frame (short-term, medium term or long-term), single decisions with multiple goals (D. J. Lee, Tipton, & Leung, 1995), or multiple decisions with a single goal (Marques, Lund, & Howitt, 2005). In this area there are studies on irrigator adaptation to climate change (Burnham & Ma, 2016; Chhetri, Subedi, & Ghimire, 2013; Epule, Ford, Lwasa, & Lepage, 2017; Esham & Garforth, 2013b; Feola et al., 2015; Rial-Lovera, Davies, & Cannon, 2017; Shackleton, Ziervogel, Sallu, Gill, & Tschakert, 2015; Webber, Gaiser, & Ewert, 2014; Wichelns, 2016), crop management decisions (Daxini et al., 2018; Dury, Schaller, Garcia, Reynaud, & Bergez, 2012; Pautasso et al., 2013; Webber et al., 2014), adoption of technologies (Alcon, Tapsuwan, Martinez-Paz, Brouwer, & de Miguel, 2014; Car, Christen, Hornbuckle, & Moore, 2012; Tripp, 1996; Ziervogel & Downing, 2004), post-harvest decisions (Stathers, Lamboll, & Mvumi, 2013), decisions to enter or exit farming (Gras, 2009; Ingram & Kirwan, 2011) and retirement or farm succession decisions (Conway, McDonagh, Farrell, & Kinsella, 2017; H. Downey, Threlkeld, & Warburton, 2017; Grubbstrom, Stenbacka, & Joosse, 2014; Joosse & Grubbström, 2017; S. Wheeler, Bjornlund, Zuo, & Edwards, 2012). There are also studies with a focus on short-term decisions (Andriyas & McKee, 2013; Gómez-Limón & Martínez, 2006; H. Lee, Bogner, Lee, & Koellner, 2016) and longer-term decisions (Gras, 2009; Joosse & Grubbström, 2017; Morais, Binotto, & Borges, 2017; S. Wheeler et al., 2012). However, we are unaware of any previous attempt to bring together this extensive literature to search for emergent patterns and identify knowledge gaps.

Given the significant volume of existing literature on the topic of irrigators' decision-making, this study conducts a comprehensive review of the literature related to irrigators' decision-making in a systematic manner, to show opportunities and gaps in the study of decision-making by irrigators. It does this by providing a broad high-level decision-making framework that can be used for future modelling studies. The framework proposed in this study complements decision making frameworks in existing studies that are mainly focused on particular types of decisions (frameworks with a focus on farmers' intuition - (Nuthall & Old, 2018), Adoption of technology - (Edwards-Jones, 2006), focus on farmers' attitude and objectives in decision-making (Willock, Deary, Edwards-Jones, et al., 1999), farm management decisions(Öhlmér, Olson, & Brehmer, 1998), and climate change adaptation - (Feola et al., 2015). By assuming that decisions are highly dynamic and interrelated to each other, it also provides an overarching approach to the decision-making process without restricting decisions on their scope and/or timeframe.

2. Methods

The overall approach to identifying and analysing existing literature is provided in Figure 1. We used a systematic method to identify relevant publications, reducing the large volume of information from the literature into a more succinct form for synthesis (Mulrow, 1994). We then used qualitative data analysis (Content Analysis) to analyse the trends or patterns underlying the included articles (Stemler, 2001).

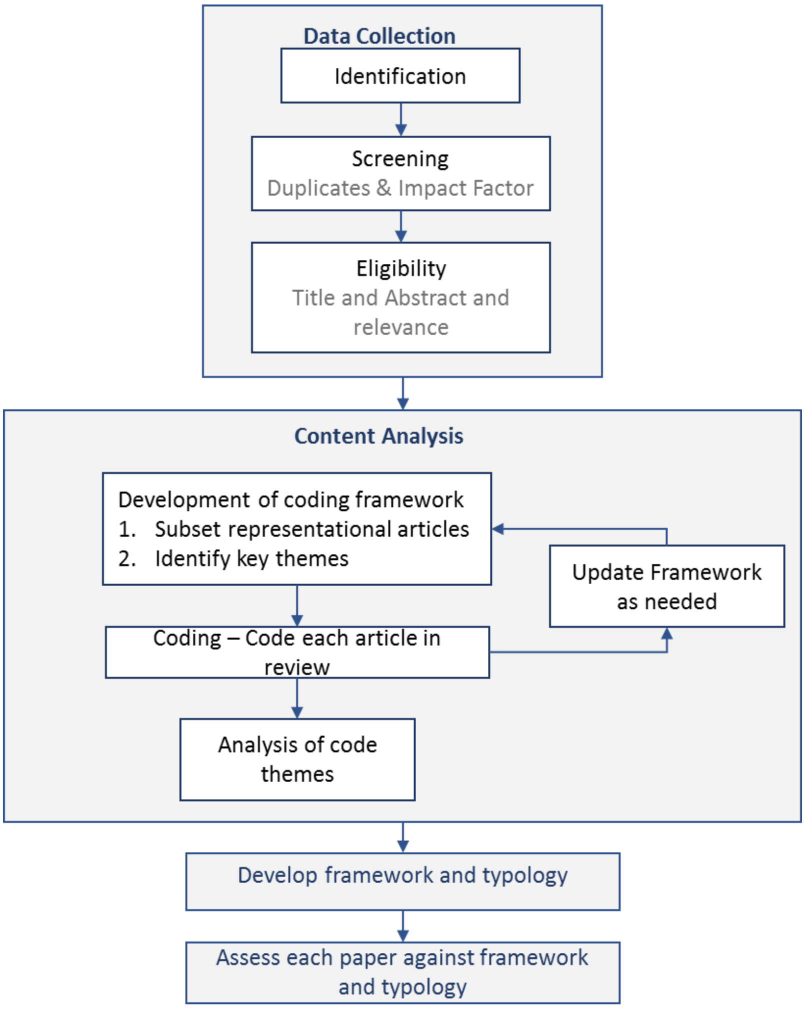


Figure 1 Overview of methods used for the analysis – A systematic method was used to identify key articles, and Content Analysis was used to analyse the literature.

2.1 Data Collection

We identified relevant journal articles based on key terms in the title and abstract (Appendix I). Combinations of the search terms “irrigators” with “decision-making”, “behaviour”, or “behavior” were used in the databases “Scopus”, “Web of Science” and “Engineering Village”. The search excluded topics such as fisheries, forestry, dryland farming and rain-fed farming, as these generally do not use irrigation (see Appendix I and II for further details).

Once the initial search was complete, the dataset was filtered based on Journal Impact Factor and detailed abstract review (Figure 1 and Figure 2). We adopted Journal impact factor (JIF) as a rough measure of article quality with the assumption that papers with more significant scientific findings will be more likely to be published in higher impact factor journals (Aarssen et al., 2008). The journal lists with corresponding JIF were obtained from Thomson Reuter’s 2016 InCites Journal Citation Reports.

Following this initial screening, the dataset was further reduced through detailed reading of the title and abstract to remove non-relevant research. This type of subjective screening was necessary to remove papers that fit the keyword search but were not related to decision making by irrigators. We recorded a short description justifying the choice to include or exclude each paper.

2.2 Content Analysis

We used Inductive Content Analysis (CA) in this study to evaluate the contents of the selected articles. Inductive Content Analysis is a qualitative data analysis method that allows us to summarise large volumes of texts by developing a set of categories or themes that emerge from reading the text (rather than being pre-determined), and then coding[1] data to these themes (Erlingsson & Brysiewicz, 2017). Analysing the coded data in each theme allows the researchers to reach meaningful conclusions about the data. The data management tool NVivo Pro 11 was used to manage the data.

We started the analysis by conducting a Word Frequency Query (Figure A. 3 and Table A 3 in Appendix II) on the full content of each paper to find the frequently occurring words or concepts in the database. The objective of this step was to provide an understanding of the major topics discussed across the articles, which would help to find possible themes before starting the inductive analysis. The word frequency analysis was undertaken using the ‘Word frequency query’ function in NVivo.

We developed an initial set of themes with the help of word frequency query and by reading the contents of 20 selected articles (selection was based on the types of decisions they considered for analysis), and then iteratively developed a coding framework[2] by reading the rest of the papers and continuing to extend and edit the framework. Once the coding framework was finalised, the relevant texts of each article were coded, i.e. categorised into the relevant themes (referred to as coding).

[1] As per Saldana (2015), the coding in qualitative analysis refers to “A word or short phrase that symbolically assigns a summative, salient, essence-capturing, and/or evocative attribute for a portion of language-based or visual data”.

[2] Coding Framework (thematic framework) means the sets of themes or codes into which the data are broken down (Bryman & Burgess, 2002).

We then analysed the data that had been coded into each theme further to summarise the full range of data within each theme (Appendix III).

Finally, a high-level decision-making framework emerged after considering all themes and determining how each of the different elements contributed to the decision-making process. We also performed a further stage of analysis in which articles were categorised based on the research method and the time-frame over which the decisions were studied in the articles. The research method of each articles was classified into Quantitative, Qualitative and Mixed methods to understand how the contributions differed by method. After categorising the articles into the three research methods, we closely examined studies in each category of methods to determine the time-frame for decisions studied in the articles. We adopted the typology used by Risbey et al. (1999) to categorise various decisions over different time-frames.

3. Results

3.1 Data Collection

The journal article count through search terms was 798, which was subsequently reduced to 312 by using JIF and then to 151 after filtering based on information in the title and abstract of each paper (Figure 2). The key reason for selection or rejection of each of 312 articles are summarised in the supplementary material.. The details of the articles selected for our study are provided in Appendix II.

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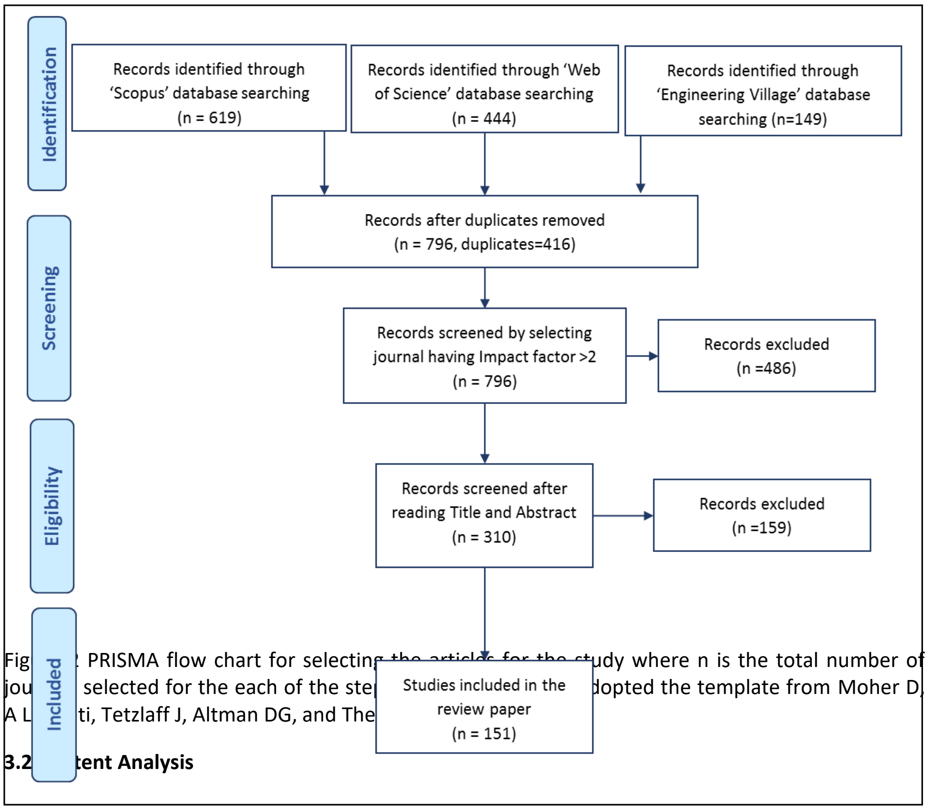

Fig... 2 PRISMA flow chart for selecting the articles for the study where n is the total number of jou... selected for the each of the step... adopted the template from Moher D, A L...ti, Tetzlaff J, Altman DG, and The...

3.2 ...tent Analysis

The themes identified at the initial stage of the analysis (mainly from word frequency query analysis) were then iteratively reduced to eight: *Decisions, Drivers, Influencing factors, Impact of the Decisions, Representation and Data Collection* (Table 1). The themes *Decisions, Drivers, Influencing Factors and Impact of the Decisions* help to describe the nature of the decisions and the decision-making process itself. The themes-*Representation and Data collection* help to explain how these decisions are studied in literature.

Table 1 Description of each theme with examples of codes for each theme

Themes	**Descriptions**	**Examples from Khanal, Wilson, Hoang, and Lee (2018)**
Decisions	Details of the decisions undertaken by irrigators	"Our findings show that approximately 72% of the **farming households had adopted at least one adaptation strategy** in response to adverse impacts of climate change."
Drivers	Main drivers or goals behind the decisions	"To identify true **climate change** adaptations, we link the farmers' adjustment in farm management with particular climate change impacts in rice production."
Influencing Factors	External and internal factors that influence the irrigators in undertaking the decision.	"Our results show that **farmers' education, access to credit and extension services, experience with climate change impacts such as drought and flood, information on climate change issues, belief in climate change and the need to adapt** all variously determine their decision-making."
Impact of the Decisions	The result or impact of the decisions.	"We find that the adaptation strategies employed by farmers significantly **increase rice yields**'
Representation	The way the decision is represented or modelled in the study.	"We, therefore, estimate **a simultaneous equations model with endogenous switching** to account for selectivity bias and capture the differential impact of adaptation on adapters and non-adapters."
Data Collection	Details of the data collection mode	"A combination of two different methods was used for data collection. They include **focus group discussions (FGDs) and household surveys**."

3.3 How irrigators make decisions?

In developing the high-level decision-making framework (Figure 3), some of the themes were used as is (*Decisions, Impact of the Decisions*) and others were split into two sub-themes based on their influence on decision-making behaviour (*Drivers and Influencing factors*). The theme '*Drivers'* was split into two sub-themes: i) the "*Driving force*", which is the main external stimuli behind the decisions; and ii) "*Goals*", which are the irrigators' desired outcome when making decisions. (Barbieri & Mahoney, 2009) demonstrates the hierarchical nature of goals, with many lower order goals and a smaller number of higher order goals. When a farmer makes a decision driven by external stimuli and goals, there are certain factors that influence the decision-making process (the theme "*Influencing Factor*"). These influencing factors can be either i) "*Extrinsic Factors*", which are the external conditions that control the situation and ii) "*Intrinsic Factors*", which are intrinsic to the farmer. Two irrigators subject to the same driving forces and goals may make different decisions because of different extrinsic and intrinsic factors. The decision-making process normally involves choosing from a set of options or deciding to act or not to act for certain external or internal stimuli. The application of this framework across three different time-scales is illustrated in section 3.3.1 by drawing examples from articles in the database.

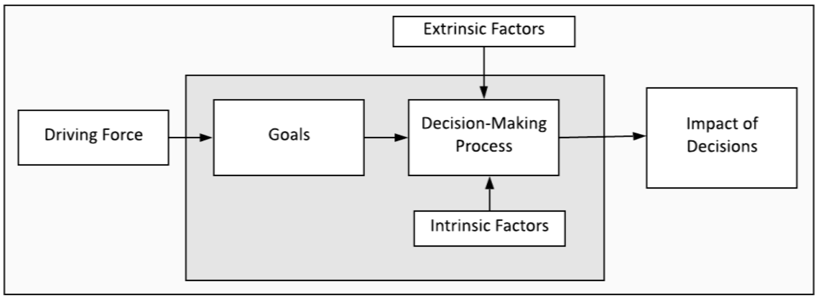

Figure 3 High-level decision-making framework.

Different irrigator decisions occur at different temporal scales (Table 2). We have adopted the classification of decisions and temporal frame suggested by Risbey et al. (1999) which distinguishes tactical (less than one year), strategic (one to five years) and structural (five years plus). The typology of decisions and key examples for each of the elements in the decision-making framework are given in Table 2 (a detailed list of elements is included at Appendix V). Please note that some decisions can come in more than one time-frame depending upon the scope of the decisions. For example, income diversification can come in both strategic and structural decisions depending upon the types of diversifications – if the decision is to migrate temporarily this can be a strategic decision but if it is a permanent migration, this comes in structural decisions as its impact is longer than five years (Table 2).

Table 2 Typology of decisions and examples of the key elements of the decision-making framework.

Elements of the decision-making framework		**Key Examples**
Decision	Decision type (Adopted from Risbey et al. (1999))	
	Tactical decisions (less than one year)	Decisions on crop variety Decision on water source Water use decisions Land use decisions Crop management activities Income Diversification (Off-farm income)
	Strategic Decisions	Decision on crop diversification

	(one to five years)	Income Diversification Enterprise diversification Technology Adoption Permanent water trade Seasonal migration Expand or contract farm land Expand or contract water assets
	Structural decisions (great than five years)	Farm exit Retirement Farm succession Migration
Driving Force		Climate change Climate variability Extreme events Market demand of a crop or its alternative Crop water demand Ageing, illness, divorce or sudden death
Goals		Farm viability Maximise yield Minimise loses Minimise exposure to risk Water use efficiency/farm input efficiency Maximise profit Stabilize income, or reduce debt Lifestyle objectives Environmental conservation Farming Continuance, or farming exit
Intrinsic factors		Farmer characteristics Risk appetite Family structure Existing farm debt levels Farming experience Past experience in undertaking similar decision Attitudes, beliefs and/or perceptions Off-farm income sources
Extrinsic Factors		Market fluctuations Distance from market Adaptation option range (e.g. access to insurance) Neighbourhood effect Social, political and economic conditions at the location

3.3.1 Application of the high-level decision-making framework across different time-frames

The high-level framework illustrates different elements contributing to the decision-making process and can be used for studying decisions under all three time-frames: tactical, strategic and structural (Table 2). In order to demonstrate this, we applied the high-level framework to decisions on three time-frames to three articles chosen from the database (Figure 4) from Patt, Suarez, and Gwata (2005), Figure 5 from Alcon et al. (2014) and Figure 6 from Peel et al. (2016)). The decisions described in these three articles exclusively represent the decisions in the three timeframes rather than having an overlap among different time-frames.

The focus of the study by Patt et al. (2005) (Figure 4) is the effect of climate forecasts and participatory workshops on farmers' cropping decisions (a tactical decision). Climate change and the associated drought are also listed as driving forces. The main driving force of their decision was the receipt of forecast information (which has relevance because of increasing drought due to climate change). They can decide either to modify their cropping patterns based on this forecast information with a goal of improving harvest, or not, using the forecast information (decision-making process). This decision is influenced by several extrinsic factors such as the method of communicating the forecast to the farmers, the reliability of the forecast information, whether the farmer has access to credit, whether they have access to forecast workshops and several intrinsic factors such as whether the farmer believes the forecast or not, how much they already know about the forecast, and/or their willingness to make changes to their decisions in response to any new information. For the farmers who modified their cropping pattern using the information they receive, the researchers observed an improvement in their crop yield (Impact of decision).

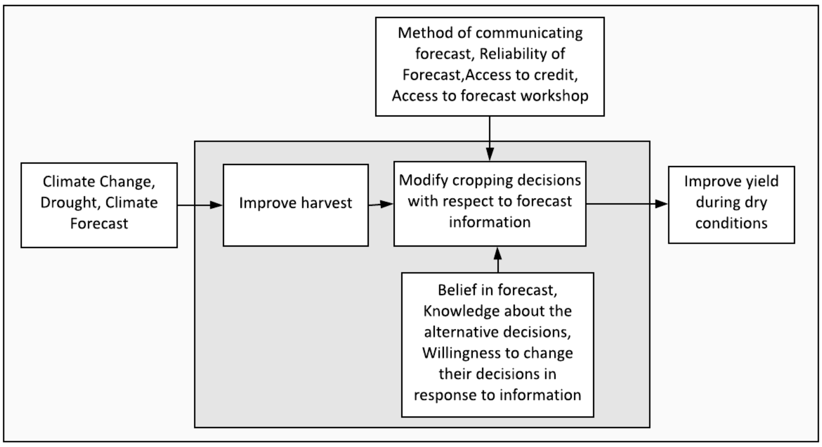

Figure 4 Crop management decisions based on climate forecast– tactical decisions (from Patt et al. (2005)) applied to the high-level framework

The focus of the study by Alcon et al. (2014) (Figure 5) is irrigators' adoption of deficit irrigation technology in response to water scarcity in the region (a strategic decision). The *driving forces* were water scarcity driven by drought and the price of water in the basin. The irrigator – with *a goal* of saving water and maximising productivity, profit and yield – makes a decision to adopt (or not) deficit irrigation technology *(decision-making process)*. This decision-making process is influenced by several *extrinsic factors* such as crop type, price of installing the technology, access to credit, extension services and the compatibility of the technology with their existing infrastructure, and *by several intrinsic factors* such as their awareness of the technology, and their interest in exploring new technology. Irrigators who adopted the technology saw an increase in crop quality. They were able to advance their harvesting season, stabilise their yield and income, and gained control of excessive foliage growth during the vegetative growth phase *(impact of the decisions).*

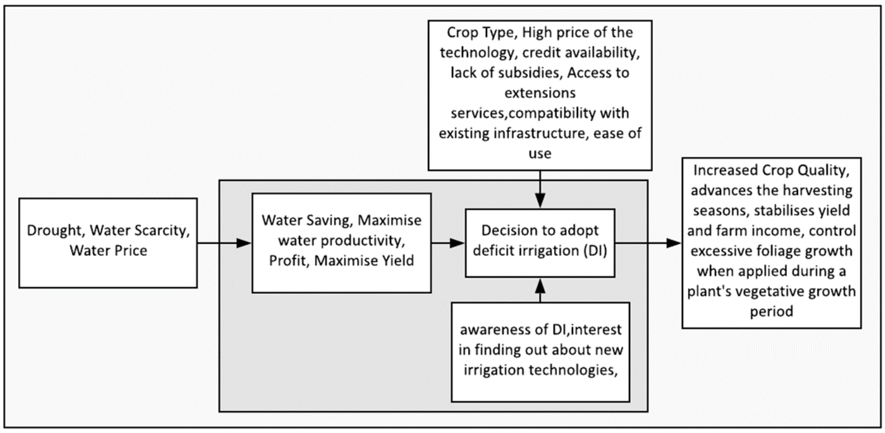

Figure 5 Decision to adopt Deficit Irrigation Technology (DI) -strategic decisions (from Alcon et al. (2014)) applied to the high-level framework

The focus of the study by Peel et al. (2016) (Figure 6) is the relationship between farmers' exit from farming and their well-being (a structural decision). Because of changes in technology, productivity, economic policies, and market conditions—or because of the fact that they are getting older (which makes it difficult for them to maintain a viable farm; *driving forces)—the* farmers are forced to make a decision to exit from farming *(decision-making process),* with *a goal* of retirement from farming in pursuit of alternative career opportunities. This exit decision is influenced by the *extrinsic factor* of assistance provided by the government to the exiting farmer and the *intrinsic factors* such as their age, education, profitability of the farm, farm size and the proportion of their off-farm income. The researchers observed an adverse effect of farm exit process on farmers' well-being. Since the focus of the study was mainly the relationship between the farm exit process and wellbeing, they have not explained in detail about how farmers actually exit from farming – either by selling their property and water rights or by intergenerational farm transfer (farm succession).

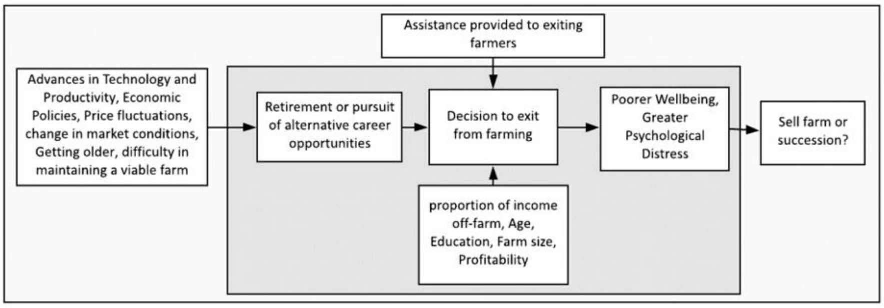

Figure 6 Decision to exit from farming - structural decisions (from Peel et al. (2016)) applied to the high-level framework

3.4 What decisions are examined in the literature?

We categorised the literature based on the decision types discussed in each article (Figure 7 and Table A 6 in Appendix IV). The largest group of articles discussed the combination of tactical and strategic scale (57 out of 151 articles) and a small number of articles represented the wider timeframe of tactical, strategic and structural decisions (4 articles).

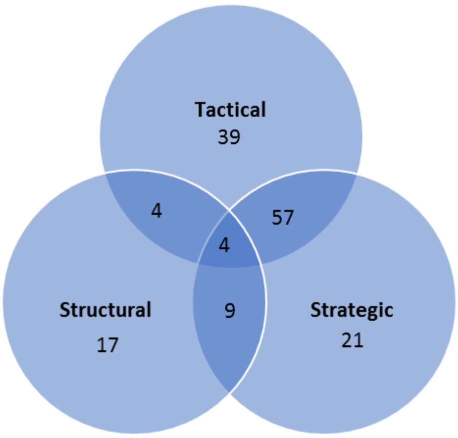

Figure 7 Classification of literature based on the decision types

3.5 How does the literature model irrigators decision-making process?

After categorising the studies into three research methods (qualitative, quantitative and mixed-methods), we investigated which decision types (Table 2) were discussed in the majority of the papers (Figure 8). The majority of the articles using quantitative methods are studied either in tactical (18 articles) or in both tactical and strategic decision (18 articles) types. The majority of the articles using mixed methods are also in tactical and strategic decision types (26 articles). In contrast, the majority of articles using qualitative methods are structural decision types (10 articles).

We further analysed the sub-categories of studies that described the majority of the decision types in each approach to understand how they described the decision-making process (Table 3). Crop and water management decisions are discussed in both quantitative and mixed methods at a higher frequency, while structural decisions such as farm succession and farm exit are discussed in qualitative methods journal. The methods move from quantitative to qualitative as the timeframe of the decisions shifts from tactical to structural. For example, the decision to invest in infrastructure (strategic decisions) is in a 'secondary' category in quantitative methods, while it is in a 'key' category in mixed methods and not listed in qualitative methods. Similarly, the decision to diversify income (structural decisions) is in a 'secondary' category for quantitative methods, but is in a 'key' category in mixed and qualitative methods. The risks caused by climate change is the one of the key drivers in quantitative methods while climate change itself is a driver in mixed methods and the mention of climate change is less in qualitative methods.

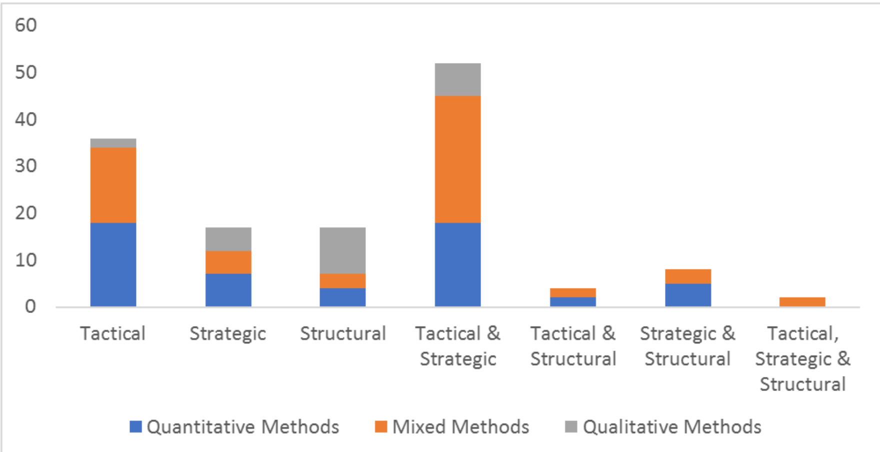

Figure 8 Decisions types used in quantitative, mixed and qualitative method

Table 3 Decisions, drivers and goals discussed in quantitative, qualitative and mixed method studies. In quantitative methods papers, tactical, tactical & strategic decisions are discussed most; in mixed methods papers, tactical & strategic decisions are discussed most; and in qualitative papers, structural decisions are discussed most and hence these papers are selected for this table.

	Quantitative Methods – Tactical, Tactical & Strategic	**Mixed Methods – Tactical & Strategic**	**Qualitative Methods - Structural**
Decisions	KEY* • Farm management decisions ○ Crop management (#27***, e.g., Navarrete & Le Bail (2007)) ○ Water use decisions (#20, e.g., Marques et al. (2006)) ○ Soil management (#9, e.g., Ngwira, Johnsen, Aune, Mekuria, & Thierfelder (2014)) ○ Fertilizer or other input management (#6, e.g., Arbuckle, Morton, & Hobbs (2015)) • Technology adoption (#6, e.g., Schuck & Green (2001)) • No adaptation against any changes (#5, e.g., Abid, Scheffran, Schneider, & Ashfaq (2015)) • Water market participation (#4, e.g., Jamali Jaghdani & Brümmer (2016)) SECONDARY ** • Farm management decisions ○ Weed Management (#1, Raymond & Spoehr (2013)) • Invest on infrastructure (#2, e.g., Sahoo, Loof, Abernethy, & Kazama (2001)) • Seasonal migration (#2, e.g., Abimbola Longe & Oyekale (2013)) • Renting out land or take land out of production (#2, e.g., Schuck & Green (2001)) • Income diversification ○ Financial strategies – credit (#2 e.g., Yegbemey, Yabi, Heubach, Bauer, & Nuppenau (2014)) ○ Investment in off-farm income opportunities	KEY • Farm Management decisions ○ Crop Management decisions (#24 e.g., Dury, Garcia, Reynaud, & Bergez (2013)) ○ Water Management decisions (#16 e.g., Niles, Lubell, & Brown (2015)) ○ Soil Management Decisions (#11, e.g., Jorgensen & Termansen (2016)) ○ Manage fertilizer or other inputs (#6, e.g., Le Dang, Li, Bruwer, & Nuberg (2014)) • Invest on infrastructure (#15, e.g., Ebi et al. (2011)) • Technology Adoption (#9, e.g., Islam & Nursey-Bray (2017)) • Income diversification (#9, e.g., Esham & Garforth (2013)) • Migration (#4, e.g., Su et al. (2012)) • Not making any adaptation (#8, e.g., Burnham & Ma (2017)) • Invest in insurance (#4, e.g., Jin, Wang, & Gao (2015)) SECONDARY • Farm Management decisions ○ Weed management (#1, Khanal, Wilson, Hoang, & Lee (2018)) ○ Manage workforce (#1, Le Dang et al. (2014)) • Reinforcing human and asset safety (#2, e.g.,	KEY • Retirement (#3, e.g., Conway, McDonagh, Farrell, & Kinsella (2017)) • Farm succession (#4, e.g., Keating & Little (1997)) • Income diversification ○ Tourism (#3, e.g., Kim & Jamal (2015)) SECONDARY • Farm exit (#1, Gras (2009)) • Migration/Resettlement (#1, Arnall (2014)) • Join farm venture (#1, Ingram & Kirwan (2011))

	(#1, Douxchamps et al. (2016))	Le Dang et al. (2014)) • Rituals (#1, Esham & Garforth (2013))	

Drivers	KEY
	• Environmental or Climate related
	  ○ Risks associated with climate change, climate variability (#15, e. g., Bryan, Deressa, Gbetibouo, & Ringler (2009), Abid et al. (2015))
	  ○ Water availability (#9, e.g.,Marques et al. (2006))
	• Farm related
	  ○ Crop water requirement (#3, e. g., Andriyas & McKee (2013))
	• Policy related
	  ○ Water price (#4, e.g., Buchholz, Holst, & Musshoff (2016), Marques et al. (2006))
	
	SECONDARY
	• Environmental or Climate related
	  ○ Weather variability (#2, e.g., Foster, Brozovic, & Butler (2014))
	  ○ Pressure to reduce greenhouse gas production (#1, e.g., Arbuckle et al. (2015))
	• Farm related
	  ○ Natural advantage (#1, Holmes & Lee (2012))
	• Policy related
	  ○ Water quota (#1, Buchholz et al. (2016))
	  ○ Pressure from authorities to increase production (#1, D. J. Lee, Tipton, & Leung (1995))
	  ○ Introduction of water market (#1, Wheeler, Bjornlund, Zuo, & Shanahan (2010))
	• Economy related
	  ○ Economic value of water (#2, e.g., Gómez-
		KEY
		• Climate Change (#25 e.g., Reidsma et al. (2015))
		SECONDARY
		• Ongoing changes of economy and regulations (#1, Dury et al. (2013))
			KEY
			• Pressure to adapt the farm against changes (i.e., globalisation of agriculture, climate change, developments) (#5, e.g., Knowd (2006))
			• Illness, Ageing or sudden death (#3, e.g., Downey, Threlkeld, & Warburton (2017))
			SECONDARY
			• Debt burden (#1, e.g., Gras (2009))
			• Emotional stress of older irrigators or reluctance to step aside from farming (#2, e.g., Conway et al. (2017))
			• Pressure from Government to make decisions (#1, Arnall (2014))

	Limón & Martínez (2006)) ◦ Changes in global economic conditions (#1, e. g., H. Lee, Bogner, Lee, & Koellner (2016)) ◦ Economies of density (#1, Holmes & Lee (2012)) • Market related ◦ Crop price fluctuations (#1, H. Lee et al. (2016)) ◦ Utility generated by resources (#1, Gómez-Limón & Martínez (2006)) • Social • Observation of neighbours' action (#1, Andriyas & McKee (2013)) • Population growth (#1, e.g., Foster et al. (2014))		
Goals	KEY • Income related ◦ Profit Maximisation (#9, e.g., Marques et al. (2006)) ◦ Secure or increase Income (#4, e.g., Douxchamps et al. (2016)) ◦ Maximise utility or benefit (#4, e.g., Ngwira et al. (2014)) • Yield Related ◦ Improve or maximise Yield (#9, e.g., Belhouchette, Blanco, Wery, & Flichman (2012)) ◦ Reduce the risk of crop loss (#5, e.g., Lefkoff & Gorelick (1990)) • Environmental conservation ◦ Water saving (#3, e.g., Andriyas & McKee (2013)) SECONDARY • Income related	• Income Related ◦ Adequate and secure income (#3, e.g., Zimmerer (2013)) • Yield Related ◦ Reduce the risk of crop loss (#4, e.g., Nidumolu et al. (2016)) ◦ Improve or maximise Yield (e.g., Galdies, Said, Camilleri, & Caruana (2016)) SECONDARY • Income Related ◦ Profit maximisation (#1, Dury et al. (2013)) • Yield Related ◦ Improve or maximise Yield (#2, e.g., Galdies et al. (2016)) • Farm related ◦ Improve soil fertility and moisture retention capacity (#2, e.g., Furman, Roncoli, Nelson, & Hoogenboom (2014))	KEY • Derive additional income (#3, e.g., Ingram & Kirwan (2011)) • Farm viability (#4 e.g., Grubbstrom, Stenbacka, & Joosse (2014)) • Business growth (#3, e.g., Keating & Little (1997)) • Farm continuity (#3, e.g., Joosse & Grubbström (2017)) SECONDARY • Enable the older irrigators to stay on the farm (#1, Ingram & Kirwan (2011)) • Desire to give new entrants a start in farming (#1, Ingram & Kirwan (2011)) • Balancing emotional bonds to family with business goals (#1, Grubbstrom et al. (2014))

	◦ Reduce the risks of price fluctuations (#2, e.g., H. Lee et al. (2016)) ◦ Reduce the cost of production (#2, e.g, Schuck & Green (2001)) • Yield Related ◦ Improve crop quality (#1, Navarrete & Le Bail (2007)) • Satisfying immediate food needs (#2, e.g., Douxchamps et al. (2016)) • Environmental conservation ◦ Control salinity (#1, Belhouchette et al. (2012)) ◦ Reduce soil erosion (#2, e.g., Mkanda (2002)) • Use for social and cultural event. (#1, D. J. Lee et al. (1995)) • Desire to stay on farm (#1, Wheeler et al. (2010))	◦ Facilitate water uptake by plants (#1, Furman et al. (2014)) ◦ Workload management (#1, Dury et al. (2013)) ◦ Optimise water availability (#1, e.g., Furman et al. (2014)) ◦ Increase water infiltration capacity (e.g., Jorgensen & Termansen (2016)) • Invoke blessings of gods (#1, Esham & Garforth (2013))	

*KEY decisions, drivers and goals were raised in at least three of articles in this category

**SECONDARY decisions, drivers and goals were raised in only one or two papers in this category

*** Number of journals discussed this decision, drivers or goals

4. Discussion

Decision-making is a highly complex process. The high-level framework (Figure 3) and the typology (Table 2) of the decisions provide a better understanding of driving forces and factors that impact the decision-making process of irrigators. Comparing the studies based on analysis types, namely qualitative, quantitative and mixed methods analysis (Table 3), shows the difference in focus of the articles for decisions depending on the analysis types. The quantitative and mixed methods[3] articles generally discussed the decisions on shorter time-frames and qualitative methods articles generally discussed decisions on longer time-frame depending upon the scope and contexts of the studies.

4.1 Generalising the irrigator decision-making behaviour using the proposed high-level decision-making framework

The high-level framework containing various elements contributing to the decision-making process provides a very simplistic representation of a highly complex process. We were able to draw the decisions in each of the articles in the format of the decision-making framework, even though the information related to some elements of the framework was missing depending on the scope of the paper. The examples of three articles given in section 3.3.1 provide a general understanding of how the framework is applied to different time-scales. Not all articles provide sufficient information to feed into the framework and the depth of information on each element of the decision-making framework varies among papers. For example, the focus of the paper in Patt et al. (2005) is the effect of climate forecasts and participatory workshops on farmers' cropping decisions. Detailed information about the other driving forces such as weather variability, crop price or common goals of monetary benefits are not included, but this does not mean they were not a part of the decision-making process (Figure 4). Since the focus of the study was the forecast information on the outcome, the crop management decisions were not discussed in detail. However, the high-level framework fits well to the information provided in the article.

The high-level framework provides a simplistic representation of the decision-making process, and therefore has some limitations. The main limitation is that the framework doesn't adequately capture the changes in decision-making process over time. For the same driving force, goals and influencing factors, irrigators could make a different decision in future based on his/her past experience in making similar decisions. This past experience could be captured as an intrinsic factor in the future decision-making process, and hence is compatible with the framework. But recording such information in a study would be very difficult unless a panel approach involving observations from a fixed cohort of irrigators over time was applied to the data collection and analysis. This would inform about multiple decisions variables over multiple time-frames from the same individuals. Another limitation of the proposed decision-making framework is that there is no clear boundary between different types of drivers. The distinction between different drivers is difficult in this case as we had to extract information from different articles written with different objectives and methodologies. This is evident in the examples given in section 3.3.1 where different drivers are listed in a single box. The same is applicable for other elements of the decision-making framework. This can be researched in future studies while examining different decisions of irrigators on how much each driver contributes to the decision-making framework.

[3] The studies that used mixed methods mostly used them in data collection; but the data were not analysed simultaneously. Instead, the qualitative information is used to back up the quantitative analysis (Jin et al., 2015; Khanal et al., 2018; Lei et al., 2014) or vice versa (Ilbery, 1991; Le Dang et al., 2014).

4.2 Decision-making process in three research methods – qualitative, quantitative and mixed methods

The majority of the articles that discussed decisions taken over longer time-frames (structural decisions) used qualitative research methods, while the majority of articles with shorter time-frame (tactical or strategic) decisions used quantitative or mixed method (Figure 8). Examples of studies of major structural decisions include decisions to exit from farming, retirement decisions, and/or decisions to nominate a successor (Conway et al., 2017; H. Downey et al., 2017; Grubbstrom et al., 2014; Knowd, 2006). The reason for using qualitative methods to study structural decisions may be because where decisions are not well defined, factors are unknown, or there are no well-validated quantitative measures for the known factors (e.g. changes in policy, economy, market conditions or climate, which are some of the major driving forces behind the decision to exit farming (Figure 6)). In such cases, qualitative methods such as face to face semi-structured or unstructured in-depth interviews may provide the best source of information. However, some of the elements of these structural decisions might then be best studied using quantitative methods such as qualitative comparison analysis (QCA) based on discreet or fuzzy sets (Rihoux, 2006). As an example, the general applicability of common-pool resource management principles to irrigation schemes might be initially examined using qualitative assessments based on water users and managers; which could then shift to a quantitative scoring and assessment of necessary and/or sufficient principles related to sustained resource use over time. Consequently, most quantitative and mixed method studies concentrate on decisions at the tactical and strategic scales (Figure 8). However, even for these decisions, some of the elements in the decision-making process might be best studied using qualitative methods. For example, irrigators' interest in finding new technologies for adoption of deficit irrigation (DI) technologies (Figure 5) or irrigators' acceptance of and belief in forecast information (Figure 4).

Different elements in the high-level decision-making framework might be best measured using either qualitative or quantitative research methods. We observed that the elements inside the grey box in Figure 3 such as *Goals, Intrinsic Factors* and *Decision-making process* mainly occur at the irrigators' scale. Understanding these decisions requires contextual knowledge about an irrigator's individual decision-making behaviour, how they made decisions, or knowledge about irrigators' immediate surrounding environment while making the decisions. Since such data is personal and context-specific, these elements may best be observed using qualitative methods, although quantitative methods such as surveys can also play a role. In contrast, the elements outside the grey boxes in Figure 3 (*Driving Forces, Extrinsic Factors, Impact of Decisions*) can be measured using existing well-defined quantitative methods. Moreover, as irrigators may not be aware of the actual cause of the driving force, the extrinsic factors or the wider impact of their decisions outside of their own scale may also not factor in their heuristics. Consider the example where a farmer makes modification to his/her crop choices based on recurrent drought. The cause of the recurrent drought can be climate change or inherent water supply variability, which can be measured (but not accurately predicted in the long-term) using climate models. However, while short-term seasonal impacts can be signalled by forward water allocation predictions, in-season allocation announcements and water-market pricing (where available), irrigators may not have adequate meteorological or climate model information to quantify the longer-term effects of climate change We should also keep in mind that not all *Driving Forces* or *Impact of Decisions* occur outside the scale of the farmer. For example, the driving forces such as ageing and illness occur at the irrigators' scale, as does *the impact of decisions* of farm exit or retirement on irrigators' wellbeing or psychological distress. However, in general, the scale separation between qualitative and quantitative methods is valid and provides new insight into how best to study different parts of the decision-making process. In general, collecting, managing and analysing related qualitative and quantitative data observations simultaneously might help us to better understand the entire decision-making process—albeit at an increased cost.

While arguing that we needed to have both qualitative and quantitative information simultaneously, it is difficult to reconcile these two types of data in a single analysis. Qualitative data collection is highly time intensive, and, by its very nature, localised to a particular setting, time and place, hence it does not contribute information on trends on a regional scale. On the other hand, it is difficult to obtain the details of some elements of the decision-making process at irrigators' scale using quantitative information, especially the decisions where high contextual knowledge is required. Even if we manage to get collect types of data simultaneously, integrating them into a single model is challenging.

Nevertheless, some studies have attempted to integrate the two methods. These integrations have taken place either at the data collection stage or during the analysis or modelling. Those studies that have collected both qualitative and quantitative data have mainly used one method to infer the analysis in the other method (Furman et al., 2014; Khanal et al., 2018; Morais et al., 2017). Some studies have attempted to integrate both qualitative and quantitative methods in modelling the decision-making process (Elsawah, Guillaume, Filatova, Rook, & Jakeman, 2015; Meinherz & Videira, 2018). These studies have mainly converted the qualitative data into a quantitative format (quantitize; Small (2011)) or converted quantitative data into a qualitative format (qualitize; Small (2011)) while doing modelling or analysis of the data. Elsawah et al. (2015) generated mental models from individual interviews and then consolidated them into a single collective map, followed by quantifying the qualitative information to feed into an Agent-Based Model. However, the model results were not presented in their study. Meinherz and Videira (2018) developed mental models out of focus group discussions and used these to generate a quantitative System Dynamic Model after converting the qualitative information into quantitative forms. The authors acknowledged that this can only be used for a few mental models. In reality, the decision-making behaviour of each farmer is different, and there would be a large number of mental models to integrate, making it difficult to integrate with quantitative models.

Capturing the dynamics of the decision-making process in terms of changing environments is also very challenging. Agent-based models (ABM) have the capacity to model the decision-making process of irrigators in response to changing environments. However, ABMs fail to store the memory of agents when undertaking similar decisions in the future, which is one of the major intrinsic factors in the decision-making process. Machine learning techniques could be used to store the memory of the agents' past decisions (Du, Cai, Brozovi, & Minsker, 2017; Nguyen-ky et al., 2018). Du et al. (2017) tried to model irrigators' water trade decisions using ABM and machine learning for a hypothetical water market scenario. However, they only used quantitative information for their model. Similar to ABM, qualitative comparison analysis (QCA) method also provides a robust and practical framework for analysing qualitative and quantitative information. Both ABM and QCA methods would be of equal value where both qualitative and quantitative data were collected for analysis, while ABM might provide quicker analytical outcomes where quantitative data alone was involved.

Despite these challenges, it is highly beneficial to integrate both qualitative and quantitative methods in a single study to get a complete picture of irrigators' decision-making process. This would better allow us to make sure that we have captured the dynamics of decision-making in a highly dynamic and complex environment. Further research is needed to have a formalised methodology for adequately capturing the decision-making process.

4.3 Implications for considering irrigators' decision-making process in policy decisions.

Irrigators decision-making behaviours are not generally considered in many policy decisions. Better knowledge of irrigators' decision-making process allows regulators to shape better agricultural policies, and may improve acceptance by irrigators of technologies that allow water managers to allocate resources fairly among different stakeholders. While designing policy around irrigators, or developing technologies or improving infrastructure, it is important to consider the various elements contributing to the decision-making process. Even though any proposed interventions are designed to benefit the farming community, a lack of consideration of irrigators' decision-making process will reduce the intended benefit of the interventions to the target audience. This is especially true of current investments into water use efficiency projects in the Murray–Darling Basin of southern Australia. Total investments funding is around AU$8.9 billion over ten years, but to date roughly 600 gigalitres has been recovered at a cost of up to AU$15,000/megalitre; where market prices averaged AU$1,500/megalitre over the same period (Adam Loch, Boxall, & Wheeler, 2016). Adam Loch et al. (2016) also showed that irrigator preferences were not considered during the political process aimed at ceasing market buyback alternatives to efficiency investments, where approximately 45% of irrigators were willing to engage if provided the opportunity. This also created stranded assets or "swiss cheese effect' in many places because of farmers exiting from the industry and leaving the infrastructure under-utilised (Adam Loch et al., 2014). Technically the modernised infrastructure improves the water allocation efficiency. However, the lack of study into farmers' decision to continue or exit farming in the face of changes in climate and economy leaves the resources underused by the target population.

Government and policymakers need to carefully consider irrigators' decision-making while making policy interventions, especially regarding the use of economic instruments such as market-based measures, subsidies, ecosystem payments or taxes (Gómez, Pérez-Blanco, Adamson, & Loch, 2018). On occasions, authorities have failed to consider all the relevant elements that contribute to decisions. For example, in initial consideration and stakeholder consultation for the Murray Darling Basin Plan in Australia, irrigators were depersonalised and were considered as a homogeneous group, while at the same time human characteristics were attributed to river systems (Heather Downey, Threlkeld, & Warburton, 2013). Consequently, authorities faced widespread criticism and protests from irrigators while implementing the plan. Another example is policy interventions such as Joint Venture schemes (JV) introduced in Cornwall (UK) to facilitate farm transfers from older farmers. These allowed younger farmers to join the business by allowing them to work together and then gradually take over the farm (Ingram & Kirwan, 2011). However, the study Ingram and Kirwan (2011) showed a deep-rooted reluctance among farmers -both old and young- to work together unless an informal relationship was already established between them prior to joining the JV. Even though policies such as JV can provide a better contribution to the economy, a lack of consideration of farmers' decision-making behaviour leads to failure in widespread acceptance to the program.

This is also the case for technological adoption from irrigators. While we invest in improving the efficiency of technologies, we fail to consider the barriers for irrigators' acceptance of those technologies. These barriers include many intrinsic and extrinsic factors of the decision-making process. For example, the acceptance of weather and water forecast information (Gilles & Valdivia, 2009; Gunda, Bazuin, Nay, & Yeung, 2017; Ziervogel & Downing, 2004) is influenced by irrigators' existing knowledge, reliability of the information, access to credit or extension services, and whether the information is associated with possible suggestions to modify their decision-making process. Although the benefit of the technology is demonstrable, irrigators may not accept the technology unless they overcome these barriers. It is important for authorities and researchers to consider this when developing any new technologies for irrigators to use. It is also important for them to consider the unintended consequences of such investments (Adamson & Loch, 2014), as well as the potential increase in future irrigator vulnerability to water supply variability under expected climate change impacts (Adamson et al., 2017). This is where multidisciplinary approaches to water management, user analysis and system constraints can provide valuable insight (A. Loch, Adamson, & Mallawaarachchi, 2014), including opportunities to engage in mixed-method studies.

In summary, irrigators' decision-making behaviour has not been adequately considered when planning many interventions related to farming communities. This has caused irrigators to under-engage with the proposed changes and hence reduced the intended benefits of the interventions. This is unfortunately true for many agricultural policy decisions that introduce new technologies to improve farming efficiency and to manage resource allocation among irrigators.

5. Conclusion

Studying irrigators' decision-making behaviour is very important for planning any intervention related to agriculture as irrigators' decisions have a large impact on the economy and global water resources. Any intervention, irrespective of its intended benefits to the farming community, would eventually fail if famers' decision-making behaviour is not taken into consideration. This research synthesised the existing literature around irrigators' decision-making behaviour in a systematic method and provided an overarching high-level framework of irrigators' decision-making process irrespective of the types of decisions which contribute to the current understanding of the decision-making process. ~~We also compared the studies based on different analysis types and demonstrated the difference in focus of the articles for decisions under different analysis types.~~

The analysis method we used to synthesise the article content has some limitations because content analysis, like any other qualitative data analysis, can be subjective and affected by authors' judgements. However, we are not aware of any alternative robust method available to do achieve such reviews, especially where the database involved contains articles written with different objectives and methodologies. We examined a range of articles studying the decision-making behaviour of irrigators without restricting the article choices to a particular discipline. Even then, the representation from disciplines such as anthropology and developmental sociology were relatively less compared to disciplines like agricultural science. We might have gained better knowledge about the intrinsic factors and goals behind the decision-making process, and also about the farmers' worldview of their own decision-making process, if we had included more articles from journals from these disciplines. This approach might not alter the structure of the proposed decision-making framework, but it would assist future studies aimed at conducting case studies among farming communities.

The proposed high-level decision-making framework is a simplistic representation of a highly complex decision-making process. The framework captures how different elements contribute to the decision-making process but doesn't adequately capture the changes in decision-making process over time. The boundaries between different types of each element in the framework is also not given since this is subjective to the individual farmer and their environment. This could be further explored in future studies by conducting case studies among farming communities.

The most important conclusion from our review is that we need to use an integrated approach of qualitative and quantitative methods to gain a complete picture of irrigators' decision-making processes without compromising on capturing the dynamics of decision-making process in a highly changing and complex environment. While this is extremely challenging, there are already approaches available for integrating qualitative and quantitative data. Further research in this area could seek to develop a formalised methodology in adequately capturing the multi-faceted details required to understand irrigators' decision-making processes.

Acknowledgments

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Appendix

Appendix I – Literature Screening

Table A 1 Keywords and search hit results in identifying the literature

Sl. No.	Search Terms	Scopus	WoS	EV
1	TITLE-ABS-KEY[4] ((farmer* OR irrigator*) AND ("irrigation decision behaviour" OR "irrigation decision behavior" OR "irrigation behaviour" OR "irrigation behavior" OR "irrigation decision*")) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)	35	26	18
2	TITLE-ABS-KEY ("farmer* decision behavior" AND irrigate*) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)	1	0	0
3	TITLE-ABS-KEY ((farmer* OR irrigator*) AND ("water use decision*" OR "water	15	11	6

[4] Searching the words only in the Title, Abstract and Keywords as per Scopus advanced search. The format is different is Web of Science (WoS) and Engineering Village (EV) where the search format is 'TS(Topic)' and 'Subject/Title/Abstract respectively'. The last search was conducted on 27-September- 2017.

	decision-making" OR "decision* to irrigate")) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)			
4	TITLE-ABS-KEY ((farmer* OR irrigator*) AND (“sowing decision*” OR “planting decision*” OR “decision to plant” OR “decision to harvest” OR “harvesting decision”)) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)	35	23	3
5	TITLE-ABS-KEY ((farmer* OR irrigator*) AND (“farm succession” OR “farm successor*” OR “farm transfer" OR "family succession" OR " Succession Decision*”)) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)	56	46	4
6	TITLE-ABS-KEY ((farmer* OR irrigator*) AND (“Leaving farm” OR “farm* exit” OR “farm* survival” OR “exit of a farm*” OR “exit farm*” OR “farm migration" OR "exit irrigation”)) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)	70	44	10
7	TITLE-ABS-KEY ((farmer* OR irrigator*) AND (“farm adjustment strateg*”)) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)	6	5	0
8	TITLE-ABS-KEY ((farmer* OR irrigator*) AND (“climate change adaptation*”)) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)	256	214	74
9	TITLE-ABS-KEY ((farmer* OR irrigator*) AND “decision*” AND (“water trad*” OR “water market” OR “sell* water” OR “purchas* water” OR “trade water” OR “buy* water “))	29	18	11
10	TITLE-ABS-KEY ((farmer* OR irrigator*) AND “decision*” AND (“upgrad* irrigation infrastructure” OR “irrigation infrastructure investment” OR “irrigation adoption”)) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)	9	7	2
11	TITLE-ABS-KEY ((farmer* OR irrigator*) AND ("decision-making*”) AND ("crop selection" OR "crop variety" OR " crop rotation*" OR "choice of crop*" OR "cropping pattern*" OR "cropping decision" OR "crop composition*”)) AND NOT TITLE (*fish* OR *forest* OR dryland OR seafood* OR timber OR tree* OR rainfed OR marine*)	107	50	21
		619	444	149
	Total	1212		

Table A 2 Exclusion Criteria for rejecting papers

Rejection Code	**Definition**
Non-Irrigated	Study conducted in a non-irrigated cropping land
Rainfed	Study conducted on rainfed (rain fed or rain-fed) crops. (excluded papers which explicitly says they are conducted on a rainfed agricultural region)
Dryland	Study conducted on dryland agricultural regions
Biofuel	Study related to production of biofuel (or biomass, biogas, biodiesel or energy crops

Fishery	Study related to the key terms Fish, Marine, Shrimp, Seafood
Pollinators	Study related to Pollinators
Livestock	Study related to Livestock (Dairy, Cattle, forage, graziers)
Forestry	Study related to Forestry (Tree, Timber, Agroforestry)
No Direct DM	The focus of the paper is not on irrigators (or irrigators') decision making

Appendix II – Descriptive Statistics of the journals selected for the Study

No of papers published in each year are given in Figure A. 1. The majority of papers were published in the last ten years. Number of papers in 2018 is low because the last search was conducted in September 2017.

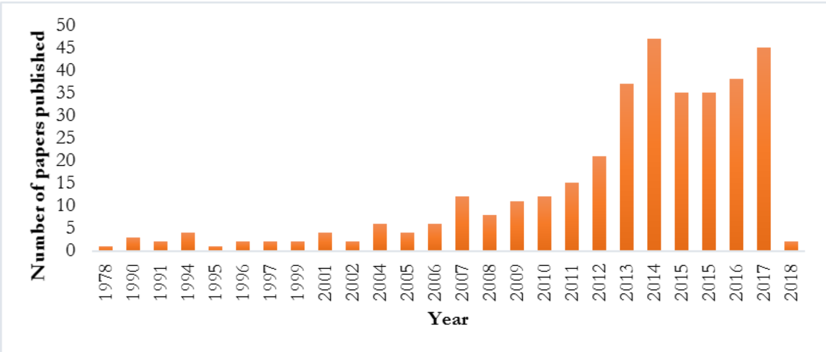

Figure A. 1 No. of Papers published in each year

The highest number of studies are reported from USA, Australia and France, with moderate number from India, China, other European countries, and parts of Africa (Figure A. 2).

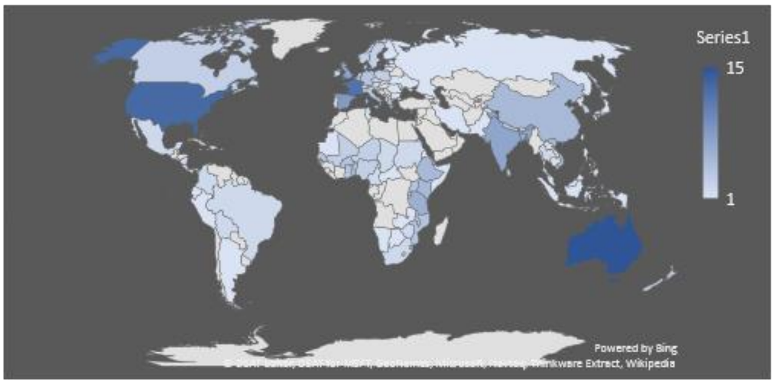

Figure A. 2 Location the study area on a global map

Table A 3 Word frequency table. The 'Weighted Percentage' is the Weighted Percentage' is the frequency of the word relative to the total words counted

Sl. No	Word	Length	Count	Weighted Percentage (%)	Sl. No	Word	Length	Count	Weighted Percentage (%)
1	climate	7	9341	0.91	26	level	5	1864	0.18
2	change	6	9023	0.88	27	area	4	1837	0.18
3	farmers	7	7130	0.69	28	decision	8	1832	0.18
4	water	5	6692	0.65	29	strategies	10	1825	0.18
5	adaptation	10	6211	0.6	30	economic	8	1751	0.17
6	farm	4	5677	0.55	31	data	4	1717	0.17
7	crop	4	5019	0.49	32	systems	7	1713	0.17
8	agricultural	12	3907	0.38	33	table	5	1700	0.17
9	irrigation	10	3787	0.37	34	rural	5	1678	0.16
10	land	4	3090	0.3	35	results	7	1633	0.16
11	agriculture	11	2764	0.27	36	social	6	1574	0.15
12	production	10	2642	0.26	37	farms	5	1564	0.15
13	model	5	2627	0.26	38	risk	4	1545	0.15
14	farming	7	2455	0.24	39	factors	7	1515	0.15
15	study	5	2444	0.24	40	analysis	8	1511	0.15
16	crops	5	2340	0.23	41	different	9	1502	0.15
17	research	8	2265	0.22	42	environmental	13	1480	0.14
18	management	10	2202	0.21	43	information	11	1479	0.14
19	farmer	6	2041	0.2	44	changes	7	1459	0.14
20	development	11	2007	0.2	45	years	5	1448	0.14
21	food	4	2001	0.19	46	farmers’	8	1441	0.14
22	soil	4	1966	0.19	47	impacts	7	1378	0.13
23	policy	6	1925	0.19	48	family	6	1347	0.13
24	rice	4	1899	0.18	49	yield	5	1343	0.13
25	local	5	1865	0.18	50	time	4	1332	0.13

Figure A. 3 Word frequency Cloud generated in NVivo

Appendix III – Content Analysis further details

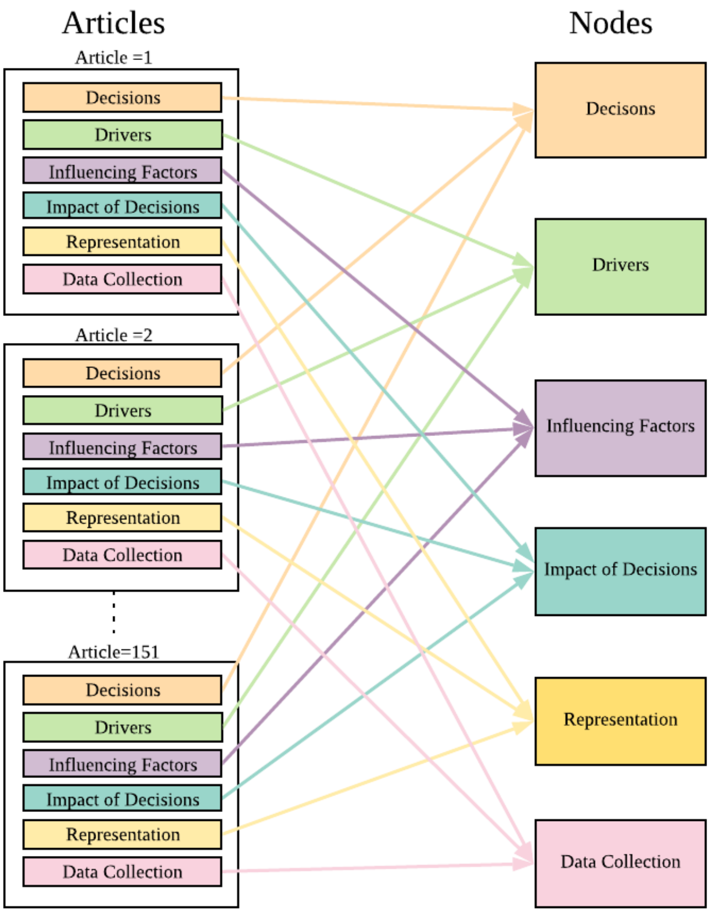

Figure A. 4 Coding during the Content Analysis

Table A 4 Number of references coded under each theme. All the references are coded in the theme "Decisions"

Please note that not all the articles contributed to each theme (as given in Table A 4 in Appendix II

Table A 5 Coding under each category of themes

Name	Sources
Decision	151
Drivers	150
Influencing Factors	123

Impact of Decisions	24
Data Collection	134
Representation	148

Appendix IV– Classification of papers based on the types of decision

Table A 6 Types of decisions captured in each article

Analysis Type	**Decision Types**	**References**
Quantitative Methods	Tactical	H. Lee et al. (2016), Navarrete and Le Bail (2007),Holmes and Lee (2012),Zapata et al. (2007),Marques et al. (2006),Belhouchette et al. (2012),Dhakal (2016),Marrou, Sinclair, and Metral (2014),Andriyas and McKee (2013),Jamali Jaghdani and Brümmer (2016),Sahoo et al. (2001),Moniruzzaman (2015),Foster et al. (2014),Gómez-Limón and Martínez (2006),Buchholz et al. (2016),Yegbemey et al. (2014),Lefkoff and Gorelick (1990),Andriyas and McKee (2014),D. J. Lee et al. (1995)
	Strategic	Fisher and Carr (2015),Cai, Mullen, Wetzstein, and Bergstrom (2013), Agbola & Evans (2012), Asrat, Yesuf, Carlsson, & Wale (2010),Hogan, Bode, & Berry (2011),Villa-Cox, Herrera, Villa-Cox, & Merino-Gaibor (2017),Bradshaw, Dolan, & Smit (2004)
	Structural	Bertoni & Cavicchioli (2016),Zagata & Sutherland (2015),Peel, Berry, & Schirmer (2016),Fałkowski (2017)
	Tactical & Strategic	Douxchamps et al. (2016),Abimbola Longe & Oyekale (2013),Mkanda (2002),Detlefsen & Jensen (2004),Z. Islam, Alauddin, & Sarker (2017),Schuck & Green (2001),Gaur, Biggs, Gumma, Parthasaradhi, & Turral (2008),Arbuckle, Morton, & Hobbs (2015),Wheeler, Bjornlund, Zuo, & Shanahan (2010),Bryan, Deressa, Gbetibouo, & Ringler (2009),Abid, Scheffran, Schneider, & Ashfaq (2015),Raymond & Spoehr (2013),Ngwira, Johnsen, Aune, Mekuria, & Thierfelder (2014),Marques, Lund, & Howitt (2005),Arunrat, Can, Pumijumnong, Sereenonchai, & Wenjia (2017),Iglesias & Blanco (2008),Poppenborg & Koellner (2013)

	Tactical & Structural	Gaydon, Meinke, Rodriguez, & McGrath (2012), Masud et al. (2017)
	Strategic & Structural	Latruffe, Dupuy, & Desjeux (2013),Marshall et al. (2014),Raggi, Sardonini, & Viaggi (2013),Wheeler, Zuo, & Bjornlund (2013),Barbieri & Mahoney (2009)
Mixed Methods	Tactical	Ziervogel & Downing (2004),Ilukor, Bagamba, & Bashaasha (2014),Takama, Aldrian, Kusumaningtyas, & Sulistya (2017),Gilles & Valdivia (2009),Richards, Bange, & Johnston (2008),Ronfort et al. (2011),Fujisawa & Kobayashi (2011),Jain, Naeem, Orlove, Modi, & DeFries (2015),Risbey, Kandlikar, Dowlatabadi, & Graetz (1999),Car, Christen, Hornbuckle, & Moore (2012),Merot, Bergez, Capillon, & Wery (2008),Gunda, Bazuin, Nay, & Yeung (2017),Lei, Wang, Yue, Yin, & Sheng (2014),Nidumolu et al. (2016),Sen & Bond (2017),Patt, Suarez, & Gwata (2005)
	Strategic	Burney et al. (2014),Laube, Schraven, & Awo (2012),Khatri-Chhetri, Aggarwal, Joshi, & Vyas (2017),Alcon, Tapsuwan, Martinez-Paz, Brouwer, & de Miguel (2014),Akter, Krupnik, & Khanam (2017)
	Structural	Morais, Binotto, & Borges (2017),Gambelli & Bruschi (2010),Wheeler, Bjornlund, Zuo, & Edwards (2012)
	Tactical & Strategic	Reidsma et al. (2015),Galdies, Said, Camilleri, & Caruana (2016),Läderach et al. (2017),M. T. Islam & Nursey-Bray (2017),Zimmerer (2013),Hoang et al. (2014),Esham & Garforth (2013),Truelove, Carrico, & Thabrew (2015),Van Aelst & Holvoet (2017),Burnham & Ma (2017),Jorgensen & Termansen (2016),Rodriguez, Cox, deVoil, & Power (2014),Jianjun, Yiwei, Xiaomin, & Nam (2015),Reid, Smit, Caldwell, & Belliveau (2007),Ebi et al. (2011),Jin, Wang, & Gao (2015),Furman, Roncoli, Nelson, & Hoogenboom (2014),Su et al. (2012),Varela-Ortega et al. (2016),K. Alam (2015),Dury, Garcia, Reynaud, & Bergez (2013),G. M. M. Alam, Alam, & Mushtaq (2016),Niles, Lubell, & Brown (2015),Bryan et al. (2013),Khanal, Wilson, Hoang, & Lee (2018),Le Dang, Li, Bruwer, & Nuberg (2014)
	Tactical & Structural	Van Aelst & Holvoet (2016), Murali & Afifi (2014)
	Strategic & Structural	Eriksen & Silva (2009),Ilbery (1991),Ward & Lowe (1994)
	Tactical, Strategic &	Rahn et al. (2014)

	Structural	
Qualitative methods	Tactical	Tsegaye & Berg (2007), Lewis, Newell, Herron, & Nawabu (2010)
	Strategic	Beckman & Nguyen (2016), Chandra, Dargusch, & McNamara (2016),Campos, Velázquez, & McCall (2014),Below, Schmid, & Sieber (2015),Biggs, Tompkins, Allen, Moon, & Allen (2013)
	Structural	Arnall (2014), Knowd (2006),Kim & Jamal (2015),Downey, Threlkeld, & Warburton (2017),Gras (2009),Ingram & Kirwan (2011),Keating & Little (1997),Joosse & Grubbström (2017),Grubbstrom, Stenbacka, & Joosse (2014),Conway, McDonagh, Farrell, & Kinsella (2017)
	Tactical & Strategic	(Stupak, 2017), (Ramirez-Villegas and Khoury, 2013),(Baudoin, 2014),(Macé, Morlon, Munier-Jolain, and Quéré, 2007),Kenny (2011),Baudoin, Sanchez, & Fandohan (2014),Tarnoczi & Berkes (2010)
	Tactical, Strategic & Structural	(Ravera, Martín-López, Pascual, and Drucker, 2016)

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