IIIEE Theses 2018:8

Turning water into wine

Exploring approaches for improved water management among five vitivinicultural sustainability programs

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Thesis for the fulfillment of the
Master of Science in Environmental Management and Policy
Lund, Sweden, September 2018

iiiee
THE INTERNATIONAL INSTITUTE FOR
INDUSTRIAL ENVIRONMENTAL ECONOMICS

Published in 2018 by IIIEE, Lund University, P.O. Box 196, S-221 00 LUND, Sweden,
Tel: +46 – 46 222 02 00, Fax: +46 – 46 222 02 10, e-mail: iiiee@iiiee.lu.se.

ISSN 1401-9191

Acknowledgements

After having spent six years at Lund University, this study serves as the capstone project of my much longed-for Master of Science degree in Environmental Management & Policy at the International Institute of Industrial Environmental Economics. These years and the research conducted for this study would not have been possible without the perpetual support of certain individuals, whom I would like to acknowledge below:

Thank you mom, for always supporting me in everything I do and for giving me all the love, food and encouragement I need at the right times;

Thank you to my beloved brother and four-legged sisters, for all the pep-talk, laughs, support and calming presence in times of stress and occasional despair;

Thank you dad, for always caring and for all your encouraging words;

Thank you Danira, Lise and Lisa for giving me the best week of my thesis life on the mountain tops of Lofoten, and for being the best and most hilarious friends I could ever wish for;

Thank you Christoffer for making my summer of thesis-writing a whole lot better; for all our little adventures; for your tireless support and for serving me delicious food all summer.

Thank you dear B23, for being the most lovely and inspiring bunch of people I have ever met, for pushing each other and myself throughout the thesis period and the whole year;

Thank you Bea for the immense support and guidance throughout the year, and especially through my thesis where you helped me out despite your highly busy schedule;

Thanks to my supervisor, who helped me frame this research;

And thanks to all staff at IIIEE for making my time at the EMP program an amazing, unforgettable time of my life.

Finally I would like to thank all the program representatives from the respective sustainability programs for participating in this study and for providing me with highly valuable information. Without you, this study really would not have happened ;)

Abstract

Wine production has been demonstrated to negatively impact on the environment in a number of ways, threatening the well being of ecosystems and a sustainable future of the industry. With a general need for reducing environmental impacts; optimization of water resources has been identified the most critical environmental aspect in relation to wine production. Yet, several studies point towards inefficient water use within the industry. Vitivinicultural sustainability programs have been created as a response to concerns of negative impacts of the industry, assisting producers to adopt sustainable production practices. However, how these programs work towards adoption of sustainable water management among program members, and how these efforts can be improved for increased water efficiencies remains largely unexplored topics. Based on identified gaps in knowledge, the aims of this research were fourfold: 1) Describe how a selected set of vitivinicultural sustainability programs are working towards improved water management among members; 2) Obtain estimates on member performance in terms of water management and relate this to findings from query 1; 3) Understand program managers' perceived drivers and barriers for improved adoption of sustainable water management among members, and; 4) Use insights from query 1-3 to identify successful means for improving adoption of sustainable water practices within wine sustainability programs. Research questions were constructed to cohere with the research aims and were inductively approached through five case studies on sustainability programs in Australia, Chile, Portugal, South Africa and USA and a literature review on relevant topics. Through a qualitative analysis of collected data, the main findings turned out as following: The examined programs make large efforts towards greater water efficiencies among members through the use of performance-indicating self-assessment systems for members on a wide range of areas relating to water management (validated by third-party audits), and by supporting members through educational events, work shops and by providing practical resources for greater adoption of sustainable practices. Member performance is primarily assessed qualitatively and no quantifications on member water use were reported. Results from programs keeping performance data suggest that efforts should be especially focused on improved irrigation water quality and storm water management. This can be addressed through increased environmental awareness through education; through demonstration of financial and environmental benefits from sustainable water management; providing resources for further member support; use of industry and regional benchmarks for member comparison; and by reducing workload for wine producers to implement sustainable water practices – which have all been highlighted as important drivers for adoption of sustainable behavior, both among case study respondents and in literature.

Keywords: Water management, Wine industry, Sustainability Programs, Vitiviniculture, Implementation

Executive Summary.

Water use efficiency has been recognized as the most critical environmental aspect of the wine industry, and a highly important indicator for environmental performance, both by wine grape growers and industry experts. Yet there are several studies pointing towards inefficient water use within the wine industry, which has also been observed among practitioners. With the projected climatic changes in terms of increased temperatures and more frequent extreme weather events, coupled with a growing global population and greater demand of freshwater resources; improved management of water is critical. This is especially true for the wine (i.e. vitivinicultural) industry, as most areas used for viticulture are causing negative water balances over time, as more water is withdrawn than is added through precipitation (Flexas et al., 2010).

Vitivinicultural sustainability programs have been created as a response to stakeholder concerns on negative impacts of the industry, often having a main focus on supporting regional wine producers in adopting sustainable production practices to strengthen overall sustainability of a region or other relevant geographical context. While some studies have been devoted to compare such programs in terms of e.g. scope and design, few studies were found to investigate what wine sustainability programs do in order to address the need for sustainable water management and how *adoption* of sustainable practice among members can be improved. In relation to this, a need to better understand driving mechanisms behind sustainable water management among program members was identified, as well as to examine whether adoption of sustainable water practices can be linked to program design or type of support that members receive from wine sustainability programs. Better understanding on these issues appear especially important as studies that have examined resource use in relation to wine production indicate that there are large variations in water use among wine producers both *within* and *between* wine producing countries. However, why these discrepancies in water use can be seen, and what sustainability programs may do in order to assist wine producers in improving water efficiency, remain largely unexplored topics. The need of investigating the identified research gaps has also been expressed in several academic papers.

Having this said, this research project adopted four distinct aims, namely to:

1) Describe how a selected set of vitivinicultural sustainability programs situated in regions under water stress currently are working to improve water management among program members
2) Obtain estimates on water consumption per unit produced wine, and indications on members' degree of adoption of program requirements on water management, in order to relate this to the above query
3) Understand program managers' perceived drivers and barriers for improved adoption of sustainable management of water resources among members
4) Use insights from the above queries to identify successful means for improving adoption of sustainable water management among wine sustainability programs

More precisely, the study aimed to identify areas of successful program design in terms of program content, assessment methods and program member support by comparing these issues between wine sustainability programs in water stressed countries which, based on a set of criteria, resulted in Australia, Chile, Portugal, South Africa and USA.

Research questions of this study were formulated so that they would address the respective aims of this research, in where answers to the three first queries would help inform the fourth aim, which was expressed in the overarching research question of the study as: *'How can vitivinicultural sustainability programs improve adoption of sustainable management of water resources among their members?'*

In order to approach the stipulated research questions, five in-depth case studies on sustainability programs within the above-mentioned countries were conducted. This involved interviewing program managers, consulting program material and other relevant literature. The study also carried out a thorough literature review in the field of vitiviniculture, sustainability schemes and water management within the industry in order to address the research aims.

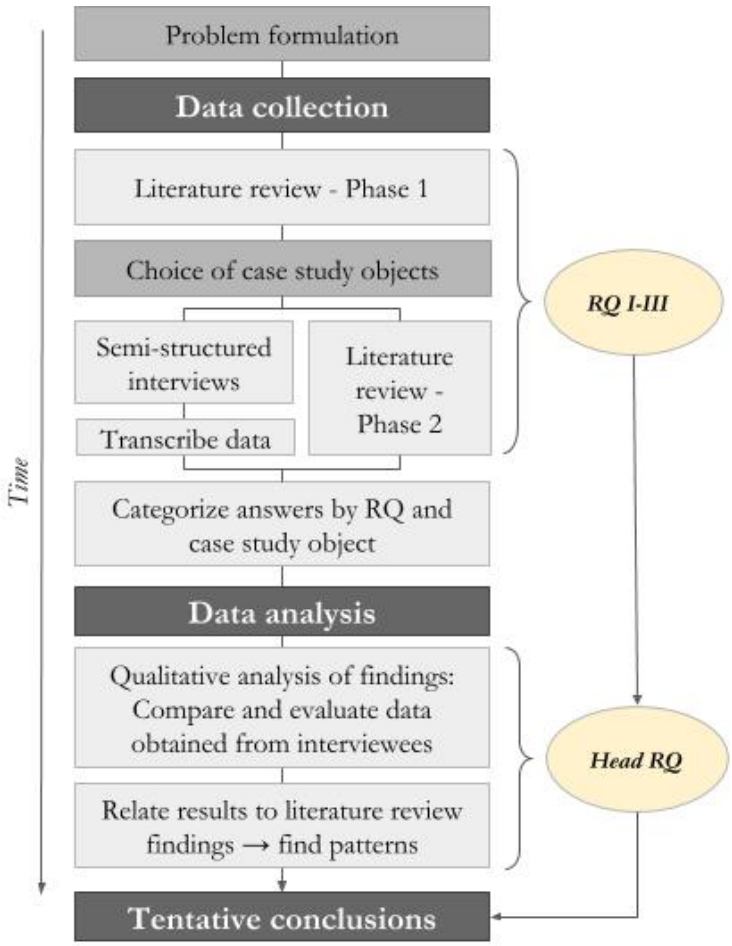

Figure I: Simplified structure of research approach.

The research carried through has been of qualitative nature, in where an exploratory approach was adopted (a simplification of the used research approach is depicted in Figure I). As this figure also illustrates; research questions *I-III* were addressed in the data collection phase, while the overarching, or head, research question was addressed in the analytical part of the discussion, which in turn supported the tentative conclusions drawn in this research.

Through a qualitative analysis of the collected data, comparing differences and similarities in relation to the different research questions, emerging patterns among the case study objects were identified. These emerging patterns were later compared (in applicable cases) and related to findings and estimates presented in the literature review chapter, in order to investigate coherence and relevance of these findings compared to existing knowledge in the field of sustainable vitiviniculture, and to draw tentative conclusions based on the research conducted.

Using the described means for addressing the fourfold research aims and questions, the following main findings were obtained:

- The investigated programs employ extensive measures for improving water efficiency among program members. In all cases, a system for self-assessment against a set of criteria on water management in the vineyard and in the wineries was found, typically summarized in a program 'Workbook'. All programs have annual third-party validation checks to ensure that reported entries to the system reflects the reality, and in four out of five cases a certification mechanisms was in place, in where accredited third-party certification bodies conduct audits against a certification standard. Assessment areas with respect to water management varied both in terms of number and amount among the studied cases, however areas of assessment remained largely similar. All programs examined provide extra support for members for improved adoption of sustainability practices; most commonly through hosting educational events, work shops, and through supplement material such as practical guides, manuals and links to informative resources. Some

programs appear to be more advanced in this respect, especially those that have been operative for a longer period of time.

- The studied programs collect data on water management performance of members in different ways. Indicators used for assessing performance are largely of qualitative nature, and no quantitative estimates on water consumption per unit-produced wine could be obtained from any of the investigated programs. Yet, three of the programs keep detailed records of member distribution within different performance categories (with respect to different sustainability practices). These records suggest that efforts should be especially focused on improved irrigation water quality and storm water management.

- Based on interview findings on program managers perception of drivers and barriers for improved adoption of sustainable water practices, factors impeding members' adoption of sustainable practices appear to primarily be a lack of education/awareness on sustainability issues; time shortages among wine producers; and perceived lack of financial benefits. The flip side of these identified barriers were instead considered drivers/success factors, along with producers' personal interest in sustainability issues; extensive support and a good dialogue with members; using sustainability performance for marketing purposes; public regional commitments on sustainability by industry actors; and the importance of top management involvement. The reported barriers and drivers were well aligned with findings from the literature review.

- Approaching the overarching research question, adapting program design according to identified findings on influencing factors for increased adoption of sustainable practices offers a good start (e.g. ensuring strong member support; providing education on sustainability issues for increased awareness; demonstrating financial and environmental benefits of sustainability practices; and striving for involvement of top managers). Adopting a requirement on members to demonstrate continuous improvements; concentrating management efforts and member support according to records on member distribution among performance areas, as well as; employing a system in where members can compare individual performance to of industry and regional benchmarks, together with practical guides on how to improve water management practices - were further identified good practices for how programs can work towards an increased adoption of sustainability practices among members.

With respect to the formulated research aims, the study was considered effectively successful considering aim one and three, while in terms of research aim two, unexpectedly little data was available, both for the examined programs as well as from previous studies. This lack in data hampered the purpose and aims of the study, as aim 1-3 were intended to inform research aim four – which was also the overarching research question of the study. Yet, obtained data were sufficient to identify some emerging patterns and provide indications on where program efforts should be directed. Together with the abundant information achieved in relation to *RQI & III* (i.e. aim 1 & 3), the overarching *RQ* could be addressed with relatively high confidence. As such, based on an extensive literature review and unique insights from program managers of the case study objects, this research has contributed with valuable insights into the field of vitivinicultural water management in terms of how sustainability programs can be managed and designed in order to increase chances for improved adoption of sustainable water practices among program members.

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Abbreviations and Definitions

CSWA – California Sustainable Winegrowing Alliance

FIVS - Federation of Wine and Spirits

Grower – Here referring to wine grape growers

IPW – Integrated Production of Wine

MVGWTA - McLaren Vale Grape and Tourism Association

OIV – International Organization for Vine & Wine

Producer – Interchangeably used for wine producers: from grape to glass

SAW – Sustainable Australia Winegrowing

SWP – Sustainable Winegrowing Program

VDC – Vinos de Chile

Viniculture – The practice of making wine, after grapes are received

Vintner – Wine producer relating to winery operations

Viticulture – The practice of growing wine grapes

WASP – Wines of Alentejo Sustainability Plan

1 Introduction

Freshwater is becoming an increasingly scarce resource as demand increases with the growing human population and the effects from climate change are becoming gradually more pronounced (IPCC, 2014). Being the largest user of freshwater, the agricultural sector holds critical responsibility in terms of ensuring efficient water management if we are to provide a sustainable future for generations to come (The World Bank, 2017; Reytar et al., 2014). Water management within vitiviniculture (the practice of growing grapes and producing wine) is of particular interest, as about 60% of vineyards occur in semi-arid areas (Flexas et al. 2010), where freshwater resources already are scarce. Recent estimates indicate that current use of water in connection with wine production typically exceeds the amounts of water received through rain (Medrano et al., 2015) – indicating unsustainable use and a negative water balance over time.

The wine industry exerts pressure on the environment not only through use and reduced quality of freshwater, but through generation of greenhouse gas emissions, solid waste, use of chemicals and land use changes, which in turn impacts surrounding ecosystems (Christ & Burritt, 2013). Out of these environmental concerns, *water* has been considered one of the most critical ones in relation to wine production (Christ & Burritt, 2013; Medrano et al., 2015; Flores, 2018; Santiago-Brown et al., 2015), given the experienced and projected declines in freshwater availability. For above reasons, several regional and national wine sustainability programs have been established across the globe to address these issues and reduce their negative impact (Flores, 2018; Santiago-Brown et al., 2014a; Corbo et al., 2014; Merli et al., 2018). These programs typically provide recommendations and hold a set of assessment criteria on sustainable practices both for vineyards (grape growing) and for wineries (wine production) (for example, see California Sustainable Winegrowing Alliance, 2014; Vinhos do Alentejo, 2018a; Vinos de Chile, 2013). How these assessment criteria vary internationally; to what degree they are being implemented by wine producers; what support producers receive in order to do so; and what drivers and barriers behind successful water management are, however remain rather unexplored topics.

Through a recent study conducted in Alentejo, Portugal, it was noted that sustainability work (e.g. in terms of water management and other resource use) among wine producers varies to a large extent within the scope of the regional sustainability program. While some producers were highly advanced, holding great knowledge and practical means for leading sustainable production, others were poorly equipped both in terms of environmental awareness and resources for achieving sustainable production. Both managers and producers of the program expressed a need to improve implementation as well as knowledge sharing of best sustainability practices among winegrowers and vintners, given the perceived potential for improved efficiencies (Angel et al. 2018)[1]. However, the study did not explore what the underlying reasons for the observed discrepancies in adoption of sustainability practices are. Thus, there is a need for investigating what drives adoption of sustainability practices among program members, and what are essential features of a sustainability program for increased adoption of these practices.

The observed inconsistencies among producers' adoption of sustainability practices in Alentejo are expected to not only apply for the Alentejo region, but for other regions and across national borders too. Through exploring and comparing the way other vitivinicultural sustainability programs are working towards improved uptake of sustainability practices among wine producers and how this affects member performance, valuable insights could be

[1] Report accessible upon request

gained into what are successful concepts for improved implementation of sustainable practices. This in turn would lay ground for tentative conclusions on best practices in terms of program design and management for greater adoption of sustainable practices. For reasons of environmental relevance mentioned above, as well as of feasibility within the frame of this research, a focus on sustainability practices in relation to *water management* is chosen for this study.

As such, this research aims to understand how different vitivinicultural sustainability programs currently are working with addressing the need of improved management of water resources among its wine-producing members, and identify good practice for achieving adoption of recommended sustainability practices. This is investigated by conducting case studies on five different vitivinicultural sustainability programs around the world, comparing their program design; their way of assessing water management among producers; how program members are supported in improving their handling of water resources; differences in reported performance; as well as drivers and barriers for greater uptake of sustainable water management among members of wine sustainability programs. The chosen case study objects for this research are operative in Australia, Chile, Portugal, South Africa and USA, which all are large wine-producing countries suffering from water stress (World Resources Institute, 2013), that have well-developed sustainability programs in place. Apart from secondary sources such as academic articles, internal documents of the different sustainability programs and reports from wine industry branch organizations; key representatives of the selected sustainability programs in the respective countries were consulted in order to gain deeper insight into these matters. With this research, the author intends to identify ways for successful program design and member support for implementing best practices in terms of sustainable water management among wine producers around the world.

1.1 Problem definition

Water use optimization has been identified as the most critical environmental aspect in the wine industry (Medrano et al., 2015), and is considered the second most important environmental indicator (after soil health) by wine grape growers and industry experts (Santiago-Brown et al., 2015). Yet there are several studies pointing towards inefficient water use within the vitivinicultural sector (Christ & Burritt, 2013; Sheridan et al., 2005; Kumar et al., 2009), which is also supported by practitioners (Angel et al., 2018). With the projected changes in climatic conditions with increased temperatures and more frequent extreme weather events (IPCC, 2014), coupled with a growing global population and greater demand of freshwater resources (Haddeland et al., 2013; The Royal Society, 2012); improved management of water is critical. This is especially true for the wine industry, as most areas used for viticulture are causing water reserves to slowly decline, as more water is withdrawn than is added through precipitation (Flexas et al., 2010). However, sustainable water use is not only important for the well being of the wine industry, but in a broader sense, for the functionality of ecosystems and humans too - especially those dependent on the same water sources as wine producers.

The need for improved water resource use is also reflected in the Sustainable Development Goals (SDGs), developed by the United Nations in 2015. Out of the seventeen developed SDGs, the most important one with respect to water is SDG 6: Clean water and sanitation – in where increased water-use efficiency, improved water quality, and protection & restoration of water related ecosystems are some of the identified targets that are to be reached by 2030 (UN Environment, 2018a). While the UN considers governments to be central actors for the implementation of the SDG, the agenda for 2030 calls for global partnership under which other actors, such as regional and international institutions, non-governmental organizations, civil society and the private sector, also holds critical roles in supporting countries and the global achievements of the SDGs (UN Environment, 2018b).

For above reasons, several sustainability programs aiming to improve resource efficiency and reduce the wine industry's negative impact on the environment and society have been created around the world (Flores, 2018). While some studies have been dedicated to investigate how these programs differ in scope and design (Santiago-Brown et al., 2014a; Flores, 2018; Corbo et al., 2014), others have suggested suitable sustainability indicators for such programs (e.g. Merli et al., 2018; Santiago-Brown et al., 2015) and some have estimated water use in relation to wine production (e.g. Bonamente et al., 2016; Lamastra et al., 2016; Quintero et al. 2014, Martins et al., 2018). The latter type of studies indicates that there are large variations in water use among wine producers both *within* countries (Kumar et al., 2009; Gabzdylova et al., 2009; Martins et al., 2018; Engel et al., 2015[1]), and *between* the countries chosen for this study (compare Amienyo, Camilleri & Azapagic, 2014; Quintero et al., 2015 and Martins et al., 2018; Kumar et al., 2009).

Still, why these discrepancies in water use can be seen, and what sustainability programs are currently doing in order to assist wine producers in improving their management of water resources, remain largely unexplored topics. From reviewing literature within this field of research, very few studies were found to cover what wine sustainability programs do in order to address the need for sustainable water management and how *adoption* of sustainable practices among members can be improved. Less so have studies been exploring what driving mechanisms behind sustainable water management among program members are; and whether this can be linked to program design or type of support that members receive from wine sustainability programs.

The need of investigating these issues is supported by several academic papers; Santiago-Brown et al., (2014a) expressed a need for investigating the impact and usefulness of sustainability programs on improving growers' sustainability, while Flores (2018) highlights limitations in terms of lack of empirical data from stakeholders of the investigated wine regions, arguing that such insights could be valuable in order to identify success factors within sustainability programs. She further stresses the importance of following up current sustainability initiatives, studying critical success factors for their continuity as well as the adherence of stakeholders. On the same note, Delmas & Toffel (2004) confirm that there is a need to better understand drivers behind adoption of sustainable behavior, as uncertainties persist regarding why some actors adopt sustainable practices more than others. In Costa et al., (2016) it is concluded that environmental issues within the wine industry remain poorly understood, and that there is a particular need for greater quantification of water use in the industry. Finally, Santini and co-authors (2013) consider it critical to approach a better understanding of *"under what conditions sustainability happens"* (p.11), and conclude through their research that the wine industry is particularly suitable for this type of research.

Having the demonstrated need for improved water management in the wine industry and the acknowledged research gaps in mind, the aims of this research are fourfold:

1) Describe how a selected set of vitivinicultural sustainability programs situated in regions under water stress currently are working to improve water management among program members
2) Obtain estimates on water consumption per unit produced wine, and indications on members' degree of adoption of program requirements on water management, in order to relate this to the above query
3) Understand program managers' perceived drivers and barriers for improved adoption of sustainable management of water resources among members

[1] Report available upon request.

4) Use insights from the above queries to identify successful means for improving adoption of sustainable water management among wine sustainability programs

More specifically, the study aims to identify areas of successful program design in terms of program content, assessment methods and program member support by comparing these issues between wine sustainability programs in Australia, Chile, Portugal, South Africa and USA. Once current program efforts and their respective outcomes have been established, this thesis aims to identify successful means for improving water management among wine sustainability programs, based on findings and patterns emerging therefrom.

By understanding why some sustainability programs are more successful than others in terms of uptake of water saving practices among its members, this knowledge can be transferred to other regions, nations and industries, thereby saving water and its associated costs.

1.2 Research questions

Based on the discussion and information provided above, the following overarching research question have been formulated in order to answer the stated knowledge gaps and stated aims for this research:

How can vitivinicultural sustainability programs improve adoption of sustainable management of water resources among their members?

In order to answer this question, a number of sub-questions are addressed throughout the paper:

I. How are vitivinicultural sustainability programs currently working for improved adoption of sustainable water management?
   a. On what areas/activities in relation to water management are sustainability programs assessing program members, and how?
   b. How are members of the respective programs being supported in improving their ways of managing water?

II. Do performance differences between the investigated sustainability programs exist in terms of water management among members? If so, what explains these differences?

III. What do program managers perceive as key drivers and barriers for better uptake of water saving practices among wine producers?

1.3 Scope and limitations

The scope of this research is limited to only entail five sustainability programs in major wine producing countries - in three of the cases regions, rather than countries (McLaren Vale region, South Australia; California, US and Alentejo, Portugal). The choice of case study objects was based on five major criteria, as presented in the methodology. As Australia and the US are countries of substantial size, and have several examples of sustainability programs on a smaller, regional scale, two sustainability programs with regional (yet extensive) coverage, that best matched the above criteria, were chosen. In the case of Portugal, only one sustainability program exist, however it has regional, rather than national coverage.

In the sphere of wine production, there is a natural division between vineyards and wineries, and many academic articles solely focus on one of the two areas of production. This study

covers water management both on vineyards and in wineries, from grape to bottle, as both parts are essential for the production of wine, and are covered by all the sustainability programs studied. Nevertheless, a clear division between wineries and vineyards are made in central documents, such as 'sustainability codes', workbooks or audit schemes of the studied programs, thus water management and the respective recommendations relating to these areas will often be discussed separately throughout the paper.

This research is limited to only study approaches towards improved water management among wine sustainability programs from a managerial point-of-view, in contrast to being occupied with studying technical details of different water saving practices, e.g. through different equipment or farming methods. Instead, the study intends to looks into structural design of the respective programs, program management efforts for supporting members with implementation of sustainable water management, as well as (by program representatives) perceived barriers and drivers for improved water management within the scope of the program. Moreover, the study is more concerned with existing practices within the studied programs, and does not investigate how sustainability programs can attract new members or grow in size as this is not part of the research objective.

When it comes to water management within agriculture, one can see two major branches of discussion in literature – one revolves around *practical, agronomic* handling of water resources (such as irrigation and cleaning practices), while the other branch deals with improved water efficiency through *genetic* modifications and attributes (e.g. GMO and use of crops that tolerate higher levels of water stress) (Medrano et al., 2015). While this research is primarily conducted through a managerial lens, it does indirectly discuss practical and agronomic means of water savings or improved water quality, (e.g. when comparing assessment criteria among programs). However, it fully excludes the latter branch from discussion, i.e. genetic plant attributes that wine growers and producers can make use of in order to reduce water use at the vineyard.

For the purpose of this research, the author has chosen to collect primary data from key actors of the respective sustainability programs, such as program representatives or experts that have been part of developing the program and/or holds great insights into program functioning and its performance. This was, in applicable cases, the person entitled Sustainability Manager, or someone in a similar position. As the structure of the different sustainability programs vary, the role of the interviewees cannot be considered identical, thus their respective insights to the actual performance of the program and its members, their recommendation on water management, as well as his or her capacity to answer the stated questions during interviews will vary accordingly, and should be acknowledged when studying the outcomes from the primary data collection. Restrictions in time and availability of the relevant interviewees limited interviews to one representative from each sustainability program. As the team operating the program typically is very small, and in some cases limited to only one person, this restriction to amount of interviewees was considered legitimate. Yet, it should be pointed out that the opinions and information provided from the interviewees might not necessarily be perfectly in line with the opinion of their respective colleagues and of the organization as a whole, as individual bias of information may occur. Due to financial, temporal and moral reasons, primary data collection from program representatives were obtained through interviews over Skype and email, rather than in-person.

As this study is examining approaches towards greater implementation of sustainable water management practices from a management point of view, program managers rather than wine producers themselves were chosen for the purpose of this research. This choice is based on the notion that managers have a better overview of program design and functioning, have greater access to necessary documents and data, as well as greater insights into overall

performance of producers, thus considered more apt for informing the research questions. Moreover, some of the selected sustainability programs have over a thousand members, which would make interviews with a small selection of producers likely to be unrepresentative.

This study is exploratory in nature and uses a qualitative approach and, as such, interviews are analyzed qualitatively and not quantitatively (e.g. through using a coding software) which might limit findings in some sense, as no statistical analysis is performed.

In terms of external limitations of the study, it might be difficult to distinguish "best performers" or to fairly compare water management across programs using absolute numbers, as there might be variances in local, regional, national and international ways of data reporting as well as in climatic conditions. In other words, in some regions wine producers might be able to dry farm (i.e. not irrigate), while others have to irrigate heavily in order to yield grapes of desired quality. Moreover, water use estimates might vary due to use of different methodologies or system boundaries when calculating total water use in the different cases under investigation. Therefore a more qualitative analysis has been made, comparing the different practices, material and communication of the different programs rather than absolute numbers.

1.4 Ethical considerations

In terms of ethical considerations for this research, the interviews with representatives of the respective wine sustainability programs investigated are the central matter. For reasons to respect the integrity of the interviewees, at the very start of each interview, the interviewee's consent to permit recording of the interview was requested. Confidentiality was also addressed by consulting interviewees on whether use of their name and their answers provided during interviews were accepted. A draft of the final version of this document will be sent to all the involved interviewees prior to the publication in order to receive their consent on the content presented in this research in relation to their respective input. In case there are comments to the text, these will be taken into consideration and adjusted for before publication.

For reasons of clarification and assurance of the objective and unbiased nature of this study, it should be noted that no external funding has been involved in this piece of research.

1.5 Audience

This paper is written for the completion of the Master of Science degree in Environmental Management and Policy at the International Institute for Industrial Environmental Economics (IIIEE) at Lund University, Sweden.

The audience for whom the output of this research is expected to be of value for, include (but is not restricted to) both practitioners and academics. The principal audience with respect to practitioners is managers, or similarly positioned actors, of sustainability programs. The content of this report will primarily be relevant to managers of sustainability schemes within the wine industry or agricultural sector, but could also be of interest for managers of sustainability initiatives outside these sectors. This identified audience could benefit from getting inspiration and greater insight into how other programs are approaching an increased adoption of sustainable water management among members. Particularly, insights into program design, content and means of member support, as well as other program representatives' perceived drivers and barriers for greater degree of such adoption will be given, which could be used in order to adjust the program accordingly. The study could also be of interest for wine producers (both growers and vintners) for whom insights into industry benchmarks and different aspects of water management considered in different programs

could be of value. Moreover, the paper provide some sources on best practices in terms of water management both at the vineyard and winery, which could be of further interest.

Other actors and stakeholders who these findings might be of interest for include those caring for a sustainable water supply within the vitivinicultural sector, such as local, regional or national governments; industry branch organizations; and actors along the supply chain of wine, who could adapt supportive actions or funding activities according to identified industry needs for greater adoption of sustainable management of water resources.

Academics, on the other hand, could benefit from this report by learning about how sustainability programs in the wine industry currently are working towards greater water efficiency in the studied countries, through the lens of managers of these programs - and how this vary among the studied programs. They would also gain greater understanding into the challenges and opportunities these programs are facing in terms of improved water management; into indications of member performance among the different programs in relation to water use; and how this relates to management practices and program design.

1.6 Outline

Below the disposition of the content of this study is presented.

The initial part of Chapter 1 introduces the nature of the problem addressed in this research which is followed by a more specific definition of what is addressed in the scope of this research and why. This is followed by a presentation of the research questions through which the aim of this research will be approached. The content then identifies research limitations, describes the intended audience and provides a thesis outline.

In Chapter 2, a literature review with the pertinent findings for the purpose of this research is given. This includes an overview of the relevant field of research, covering topics such as sustainability efforts in the industry, water us in vitiviniculture, reported water use estimates, as well as previously identified drivers and barriers for greater adoption of sustainability practices. With this background information, a greater context is brought to the research problem, which is deemed necessary in order for the reader to receive the presented findings from the case studies and the relating discussion to these in a more meaningful way.

Chapter 3 presents the methodological approach for the research conducted, including the chosen research design, means of data collection and data analysis.

Chapter 4 presents the main findings from the collected data for the respective case study objects, in relation to the different research questions, while:

In Chapter 5 the findings for the respective programs and research question investigated are qualitatively analyzed, discussed and compared. The outcome of this analysis is used to help inform the overarching research question of this study, which is also covered in this chapter.

Chapter 6 presents the main conclusions of the analysis, explains how the work contributes to this specific field of research, identifies limitations of the study and provides recommendations directed to the principal audiences. This final chapter then outlines areas for future research based on the findings made in this study.

2 Literature review

2.1 Industry initiatives for sustainable production: A broader picture

With rising concerns for environmental degradation in the late 20th century, as a result of the rapid growth in polluting industrial activities, several approaches to reduce industrial impact have been created. Some of these initiatives include environmental management systems, environmental assessment methods (e.g. Life Cycle Assessments) and integrated environmental strategies such as Cleaner Production (Dieleman, 2007). The concept of Cleaner Production has been applied in a wide range of industries, including the food industry, and has helped companies to approach environmental sustainability and improve both environmental and economic performance, generally through optimizing resource use (Vieira & Amaral, 2016; Khan, 2008). Other widespread and rapidly growing industry initiatives created as a response to global sustainability concerns include Sustainable Certification Systems (SCS). These systems or schemes typically have the same structure as any certification system (Junior, Franks & Ali, 2016); in where a certain process, product or service are delivered according a predetermined standard (typically set by stakeholders, constituents, or by a governance body), for which the fulfillment of the requirements set out in this standard is proven by a certificate or label (given after a third party audit has been conducted), in order to inform and assure stakeholders of compliance to the standard (Barry et al., 2012). A standard often consists of a set of principles, performance criteria, compliance indicators and sometimes application guidelines. Depending on the degree of voluntariness of the standard, the actors having authority for ensuring compliance varies accordingly (Barry et al, 2012). Again, this structure applies for SCS too, however these systems have a pronounced focus on sustainability issues, which typically goes beyond legal requirements, promoting corporate transparency and improved social, environmental and economic performance (Junior, Franks & Ali, 2016). Naturally, internal variations in terms of structure and function of SCS' exist, however, Barry et al., (2016) identified five elements that can be found in almost any SCS, which are: standard setting; scheme management; decisions-making about compliance; competence-evaluation of certification body and auditors; as well as labeling & marketing of the scheme. This type of certification or sustainability schemes have increased manifold over the past decades (International Trade Center, 2010), and has recently been increasingly adopted by the wine industry too (Flores, 2018, Santiago-Brown et al., 2014a).

2.2 Sustainability work in the vitivinicultural industry

2.2.1 Development and functioning of wine sustainability programs

The practice of making wine has a history of thousands of years (Chambers & Pretorius, 2010), and ensuring well-being of the vineyards has been in the interest of winemakers for many generations in the past. In recent years, with growing awareness of the scope and impacts of climate change, the need for more pronounced and concentrated efforts of ensuring sustainability in the industry has resulted in numerous wine sustainability initiatives being born around the world. The very first wine sustainability program was developed in 1992 by the Lodi Winegrape Commission in California, who a few years later developed the very first 'workbook' on sustainability practices in wine production (Szolnoki, 2013), which is a voluntary self-assessment tool for wine grape growers and wine makers (California Sustainable Winegrowing Alliance et al., 2012). It took another couple of years before the first wineries became certified sustainable, which was then made under the 'California Code of Sustainable Winegrowing Practices' (Warner, 2007). New Zealand, South Africa and Australia soon followed with their own sustainability schemes (Szolnoki, 2013), and the movement of sustainable wine programs was born.

Today, numerous organizations and programs specifically dedicated to sustainability within the wine sector exist all around the world. While most vitivinicultural sustainability programs have a national span and are governed and promoted by national institutions, some countries have several sustainability programs even within the same region (Flores, 2018; Corbo et al., 2014). In some countries an independent organization manages sustainability programs in wine production, e.g. through partnerships between official agencies and industry representatives, while in other cases organizations and local associations hold the responsibility for the framework management (Santiago-Brown et al., 2014a). Although typically containing most of the standard components of other SCS', wine sustainability schemes tend to vary in program design, scope, and content (see Corbo et al., 2014; Flores, 2018; Santiago-Brown et al., 2014a), as wine regions around the world have been creating their own regional or national frameworks in order to adapt sustainability in their respective contexts and to deal with local issues (Flores, 2018). The many different strategies and practices of approaching sustainability that have been identified within the wine industry tend to complicate international, and even national comparison in some cases (Costa et al., 2016), indicating a need for exploring individual cases, their functioning and performance.

Despite recognized differences, most sustainability programs have been identified as being voluntary in nature and having a self-assessment system in place. This system often occurs in the form of a central document, dossier or platform consisting of a number of chapters/points covering different sustainability practices, onwards referred to as 'Workbook', in where members can evaluate their individual performance against a set of assessment criteria (Flores, 2018). These criteria could for instance be in the form of check-lists or scored assessment points, stating what is required for being assigned a certain score/category (an example of such criteria is provided in Appendix A). These Workbooks are sometimes complemented with supporting documents, such as manuals, questionnaires or a practical guides that facilitate the implementation process for members by explaining *how* to reach the requirements of the program, in order to obtain a certain level, or the certificate/label under the sustainability program (e.g. Flores, 2018, Santiago-Brown et al., 2014a; Merli et al., 2018). Once a member has met the criteria set out by the sustainability program/framework, they are entitled to use a label or certificate as a proof of their commitment towards sustainable wine production (Flores, 2018), given a certification or label is part of the program. The type of assessment method used varies between programs; but typically there is a mix of qualitative and quantitative indicators or criteria for measuring member performance (Santiago-Brown et al., 2014; Corbo et al., 2014; Merli et al., 2018). The programs are in most cases divided into vineyard and winery, and sometimes include assessment criteria in all pillars of sustainability (i.e. environmental, social and economic), although environmental aspects tend to be addressed to a greater extent (Merli et al., 2018; Christ & Burritt, 2013). Commonly assessed environmental aspects include (but are not limited to) water use and quality; energy use and greenhouse gas emissions; chemical use (fertilizers, pesticides etc.); solid waste production; land use issues; and ecosystem impact (Christ & Burritt, 2013; Flores, 2018; Merli et al., 2018). The means of verifying acceptance to the program, or use of the program certificate/label, tend to be of either gradual nature – where members are provided a score or a percentage of the necessary requirements, or an in/out-basis, where members have to comply to all the listed criteria of the program (Merli et al., 2018). This type of verification is in many cases complemented with a certification scheme from an accredited third party certification body, by which in some cases, the winery/vineyard may chose from more than one option (Merli et al., 2018; AWRI, 2016, Corbo et al., 2014).

2.2.2 Policy frameworks, industry actors and central documents

What can be considered a fundamental issue in terms of sustainability within the wine sector is that there is no real consensus among growers and wine industry actors on what sustainability

actually means, likely due to the complexity of the concept, which has resulted in a number of different definitions of sustainable wine production (Santiago-Brown et al., 2014b). However, the International Organization of Vine and Wine (OIV) – an intergovernmental organization of scientific and technical nature within the wine sector – made an effort in 2004 by, for the first time, officially defining sustainable vitiviniculture in the Resolution CST 1-2004 as a:

"global strategy on the scale of the grape production and processing systems, incorporating at the same time the economic sustainability of structures and territories, producing quality products, considering requirements of precision in sustainable viticulture, risks to the environment, product safety and consumer health and valuing of heritage, historical, cultural, ecological and aesthetic aspects" (OIV, 2018).

This definition was improved in a new Resolution in 2008, through the inclusion of guidelines on environmental assessments in terms of processing, packaging and production, including water management (known as 'Guidelines for sustainable Vitiviniculture: Production, processing and packaging of products') (Flores, 2018; OIV, 2018). More recent work of the OIV in the name of sustainability include the establishment of Resolution 518/2016 called the General Principles of Sustainable Vitiviniculture - Environmental - Social, - Economic and Cultural aspects (OIV, 2017b), which acts as important guiding documents for the development of wine sustainability schemes.

Apart from the Guidelines and Resolutions of the OIV, wine sustainability programs takes inspiration from and ensure compliance with the 'Global Wine Sector Environmental Sustainability Principles' developed by the International Federation of Wine and Spirits' (FIVS) (e.g. IPW, n.d.; Vinhos do Alentejo, 2018a). FIVS is a global, non-governmental organization formed in 1951, that serves the wine, spirits, and beer sectors internationally on public policy issues by gathering and distributing information of interest to its members (consisting of producers, distributors, importers, exporters, and trade associations); as well as by advocating consensus positions to international, intergovernmental organizations and governments (FIVS, 2018).

Commonly used frameworks in the wine industry's work relating to sustainability include internationally used methodologies and standards such as the ISO 14001 and the GRI sustainability-reporting standard (Flores, 2018). In some countries, such as Australia, New Zealand and the US, it is not uncommon for wineries to be certified under ISO 14001 as a proof of dedication to sustainable production (AWRI, 2018; Corbo et al., 2014). Looking more specifically to water use within the industry, important applicable policy frameworks and international guidelines includes the SDG 6 on Clean water and sanitation (part of the 17 global SDGs developed by the UN in 2015), which sets out targets on improved water management for governments and industries across all sectors around the world (UN Environment, 2018b). On European level, the Water Framework Directive (2000/60/EC), which aims to ensure sustainable use of water resources, and the 'Blueprint to safeguard Europe's water resources' (COM/2012/0673) act as two important policy frameworks in relation to water use and quality (Costa et al., 2016).

Perhaps the most thorough piece of work specifically devoted to sustainable water management in the wine industry is the (Californian) Wine Institute´s 'Comprehensive Guide to Sustainable Management of Winery Water and Associated Energy', which is based on several decades of research in winery water efficiency, cleaning and sanitation practices, source control, process and wastewater treatment and several other winery-specific areas, and prepared by a number of industry actors (California Sustainable Winegrowing Alliance, 2014). Another important guidance document in terms of sustainable winery water use is the BEST Winery Guidebook: 'Benchmarking and Energy and Water Savings Tool for the Wine

Industry', developed by Galitsky et al., (2005), which, together with Lawrence Berkeley National Laboratory and Fetzer Vineyards, have created an integrated benchmarking and self-assessment tool for the Californian wine industry. Much of the content of these national and international policies, frameworks and guidelines on best practices presented above eventually boils down to the Workbooks of sustainability programs and are reflected in the assessment criteria of winery and vineyard-specific operations, laying ground for compliance requirements of a program certificate or label.

While there are numerous industry actors, wineries have expressed a lack of information on environmental sustainability among relevant organizations, producers and consumers (Szolnoki, 2013), indicating a need for improved cooperation and communication between these actors for optimized environmental performance (Costa et al., 2016; Christ and Burritt, Santini et al., 2013).

2.2.3 Drivers and barriers for adoption of sustainable practices

Many companies, organizations and actors in wine industry are already doing a lot to address the needs for more sustainable production. Yet, large variances in industry resource use have been reported (e.g. Kumar et al., 2009; Engel et al., 2015), and the need for greater sustainability efforts in the industry has been demonstrated (Medrano et al., 2015; Christ & Burritt, 2013). This need does not only apply to the wine industry, and for this reason a large number of studies have been devoted to understand what drives adoption of sustainable behavior (e.g. Marshall et al., 2005; Mzoughi, 2011; Rex et al., 2015; Vlek & Steg, 2007; Santini et al., 2013). Some factors have been pointed out as drivers for businesses in general, including consumer demand for sustainable products and services; stakeholder influence; resource depletion; employee engagement; capital market scrutiny; and regulatory requirements, in this case defined by the management organization 'Accenture' (Santini et al., 2013). Other external drivers that have been identified in literature include positive corporate image and reputation, product & service quality, cost efficiencies and entrance to market, while internal drivers tend to be more inclined towards exerted pressure and attitudes of managers, employee demands and social development activities (Gabzdylova et al., 2009). Especially external drivers have gained much attention while internal drivers remain less explored, particularly within the wine industry, making this a suitable industry for more research (Santini et al., 2013). With respect to the aim of this research, insights into existing studies and their insight on this topic within the scope of the wine industry is of great interest in order to better understand what drives sustainable adoption. This information is valuable for comparing how well theory align with practice and to what degree this is applied among the programs chosen as case study objects for this research.

While industry associations have been reported to have an important role in spreading sustainability awareness among wine producers (Warner, 2007; Silverman et al., 2005), an important success factor in spreading sustainability practices have been found to be the networking capacity of local actors (Santini et al., 2013). This article highlights an example from of a wine sustainability program in the Lodi region of California (Ohmart 2008), and connects its success in implementing sustainability practices (as suggested in the program Workbook) among regional wine producers to: *"the active involvement of growers that is the result of a successful combination of workshops, a proactive behaviour of associations and effective communication flows"* (Santini et al., 2013, p.2). Other drivers and barriers for adoption of sustainable practices, specific for the wine industry, that have been identified in some of the most thorough papers within this field of research are presented below.

Gabzdylova et al., (2009) made a study investigating what drives the wine industry in engaging in sustainability practices, and what the role of stakeholders are in the context of decision-

making on sustainability issues. The study was made in New Zealand, in where 31 people from 24 different vineyards and wineries were interviewed. Her findings indicate that the most important drivers in the wine industry of New Zealand, as identified among the interviewees (owners, growers, vintners and managers), are environmental values and personal satisfaction with their respective profession. Product quality and customers closely followed these top drivers, while other driving factors that were mentioned included: meeting current or future regulations; achieve market differentiation; employee/community well-being; and cost savings (although cost savings or profit were only brought up by a few) (Gabzdylova et al., 2009). Regarding the role of stakeholders, her research suggests that the most important stakeholders are owners, shareholders, customers, wholesalers and international businesses. The authors of the article link these findings to the previous question, claiming that the results are expected as personal values and opinions of owners and other shareholders were considered the strongest drivers, and the fact that customers are considered an important stakeholder agrees with her findings on the importance of product quality and customer opinion.

Marshall et al. (2005) reached similar findings to Gabzdylova et al. (2009) when investigating institutional and individual drivers for proactive environmentalism in the American wine industry. The study included interviews and focus groups with winery representatives and found that personal attitudes and values of managers (such as care for employee health or the environment) had significant impact on their adoption of sustainable practices, which is also supported by findings from Regouin (2013), who showed the importance of personal traits on this issue. Other important drivers for proactive environmental behavior identified in the study by Marshall et al. (2005) included achieving cost efficiencies, improved product quality, meeting current and future regulations, as well as promoting public image, with over half of the study participants rating these drivers as critical for motivating and sustaining environmental initiatives. Aspects such as marketing and community pressure were found to be less relevant drivers explaining environmental performance in the wine industry, based on the answers received from participants. Based on their findings, Marshall et al. (2005) conclude that there is a need for practical training and education programs focusing on the potential environmental benefits that can be achieved through sound environmental management, in firms lacking environmentally oriented values.

While Gabzdylova et al. (2009) and Marshall et al. (2005) looked more into internal drivers for greater uptake of sustainability practices and proactive environmental behavior; Flores (2018) study scope, structural design and content of six different wine sustainability frameworks (including SAW - Australia, NSC - Chile and IPW – South Africa) in order to identify main aspects, drivers and issues of wine sustainability programs. In this cross-analysis she looks into the "learning potential" of each framework, which she divides into the categories low, medium and high, and defines as *"the capacity of each framework to act as inducing factor of learning and improving practices"* (p. 2305) - which may be likened to the "success factors" discussed in the above section. Type of assessment method of the different programs were considered too, in where factors having the potential to contribute to higher learning potential were addressed, including: possibilities of comparing performance to peers; requirements on continuous improvement; and the availability of guides, practical examples and best practices. In terms of content, she studied the different sustainability aspects covered in the different central documents in each of the frameworks, as well as the "deepness" of the respective frameworks. The deepness here refers to the level of information that is available in the program material (divided into guidelines, indicators or parameters, in where "guidelines" refer to general properties of the program, "indicators", measure changes in the program guidelines, and "parameters" indicate limits for indicators as a means of control) (Flores, 2018).

For relevance to this research, her findings suggests that both the program of CSWA, California, as well as the Australian 'SAW' program had high learning potentials, while the Chilean sustainability program was considered to have medium learning potential. According to her findings, all the studied frameworks that were identified as having high learning potential were under national or regional governance, and hold all the investigated levels of information deepness (i.e. guidelines, parameters and indicators). Moreover, she recognized that providing suggestions and practical examples on improvement may be means of improving learning potential, together with ability of benchmarking performance and comparing individual practice and performance to industry best practices. Whether the program is auditable or not, i.e. having a label or certificate as part of the program, did not seem to impact the level of learning potential, according to her findings. Based on her findings and other literature on the topic, she hypothesize that learning potential is not directly related to framework structure, but rather has to do with stakeholder engagement and individuals driving the development of the program.

A study made in 2014, compared wine sustainability programs around the world (including South Africa; California, USA; Australia and Chile) in where 83 top managers from the wine industry were asked about the potential and expected benefits of participating in a sustainability program; what reasons would cause them to not participate in a sustainability program; as well as what they would do to engage growers to participate in a sustainability program if they were responsible for the implementation of it (Santiago-Brown et al., 2014a). Although these questions do not perfectly cohere with the ones investigated in this section (i.e. success factors and barriers for greater implementation) they point towards the same direction and provide valuable insights into driving and impeding forces behind stakeholder engagement in wine sustainability programs.

The findings from this extensive research study showed that education was the most important benefit participants of sustainability programs experienced, and one of the main reasons behind program participation (based on a qualitative analysis of the interviews). According to the participants, areas of learning (and self-improvement) included: program self-assessments; insights into relative performance compared to peers; interaction with other growers; and training provided by the program's management. Apart from education, the qualitative analysis identified marketing as the second most expected benefit among interviewees. "People", here referring to program managers and peers, consumers as well as local community members also showed up as an important driver for program participation (Santiago-Brown et al., 2014a). In terms of inhibiting factors for participation, "people" was mentioned a core reason here too. The author identified two categories that "people" here referred to, that were related to the (lack of) credibility of the program, in turn acting as a demotivating factor for program participation. These categories were either program managers, or program peers. If managers are perceived unfit for the role (e.g. due to lack of experience, technical expertise or personal traits), or if program peers are benefitting from the sustainability efforts of other members, without contributing themselves to the regional sustainability performance – then growers are reluctant to join or continue such a sustainability program. "Time", "cost" and "work", were the following most commonly used words in the interviews relating to inhibiting factors, according to a quantitative analysis. Lack of self-assessment appropriateness, lack of useful information to members and deficient financial improvement and/or market benefits were other factors that were identified as inhibiting, based on the qualitative analysis (Santiago-Brown et al., 2014a).

When asked about what actions they would take on in order to increase program participation and engagement, interviewees mainly referred to promoting the benefits highlighted in the previous question, as well as sharing "success stories" from current members in wine

sustainability programs. The results obtained from the quantitative analysis were similar to the ones relating to the question about inhibiting factors. Santiago-Brown et al. (2014a) explains this by concluding that the factors promoting sustainability program participation are also the same factors that inhibit wine growers to participate in such a program, i.e. there is an important balance between cost and time, versus benefits and credibility that will affect program participation. Santiago-Brown and co-authors conclude from their study that environmental issues are not the main driver for engaging in a viticultural sustainability program, but rather the overall sustainability of program members, primarily achieved through gained knowledge and economic benefits (from more resource-efficient operations), as a result of program participation. Moreover, they conclude that the success of the investigated programs could largely be linked to the individuals driving and developing these programs (i.e. program managers, innovative growers and early adopters); to the way these actors support and communicate with members/peers; as well as to the utility degree that the program proves for improving sustainability performance.

Looking to findings from industry initiatives, the California Sustainable Winegrowing Alliance (CSWA) carried out a study in 2009, partly aiming to identify wine producers' motivations and constraints for the adoption of sustainable vineyard management practices, by asking 324 wine producers that were enrolled in the sustainability program of CSWA (the SWP). Their main findings were that motivation behind adoption of sustainability practices varied depending on the practice, but were mainly related to environmental reasons, improved production or quality, cost savings or scientific support for adoption of this practice; while the main constraints identified included lack of perceived benefit or need as well as perceived costs. While the study looked into a number of sustainability practices, an important constraint to the study was exclusion of questions addressing water management efficiency, which was also pointed out by a number of participants in the study. (CSWA, 2009). While many valuable insights are gained from the studies presented above, it should be noted that a range of methods have been used when reaching these findings, which might have impacted on the results.

2.2.4 Overview Selected Sustainability Initiatives

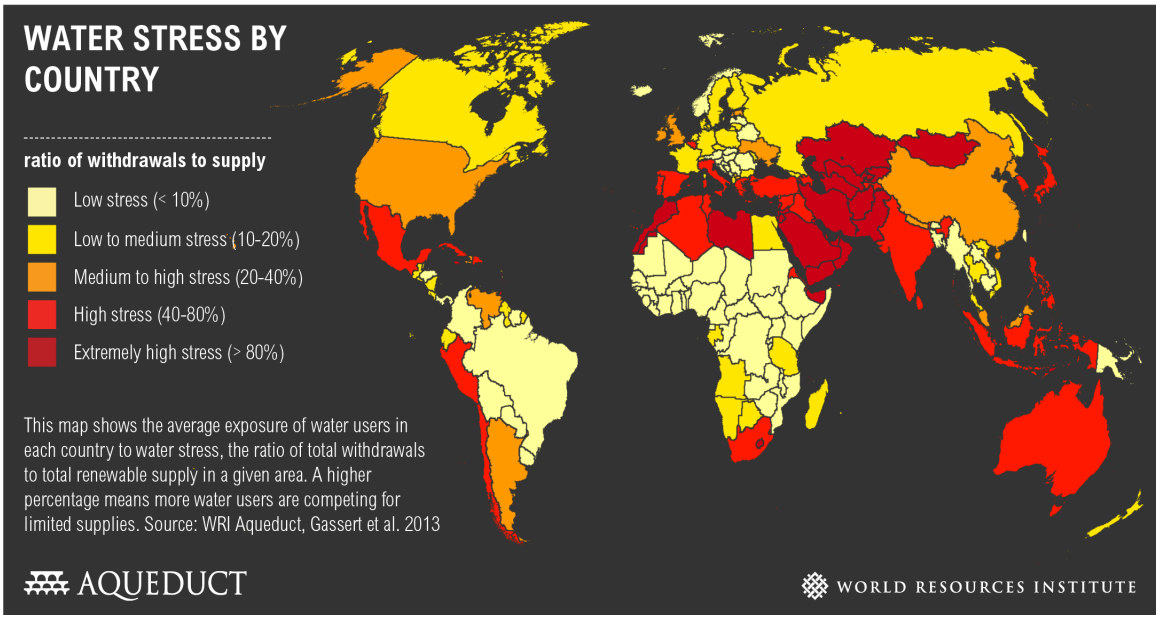

Figure 2-1: World map of the varying degree of water stress among countries. Source: World Resources Institute (2013).

As set out in the introduction chapter, this research builds on five different case studies of vitivinicultural sustainability programs in five large wine producing countries, namely: Australia, Chile, Portugal and South Africa and the US, which all are present in regions under medium or high water stress (World Resources Institute, 2013), as depicted in Figure 2-1 above. The criteria used, as well as reasoning behind the choice of these programs and countries are described in the following methodology chapter.

Below the sustainability programs chosen as case study objects for this research are briefly introduced, in where an overview of the history, scope and structure of these programs are given, summarized in Table 2-1.

Table 2-1: Overview of the selected sustainability programs.

Country	Australia	Chile	Portugal	South Africa	USA
Organization	McLaren Vale Grape Wine and Tourism Association (MVGWTA)	Vinos de Chile (VDC)	Alentejo Regional Vitivinicultural Commission (CVRA)	Sustainable Wine South Africa (SWSA)	California Sustainable Winegrowing Alliance (CSWA)
Framework	Sustainable Australia Winegrowing (SAW)	National Sustainability Code (NSC)	Wines of Alentejo Sustainability Program (WASP)	Integrated Production of Wine (IPW)	Sustainable Winegrowing Program (SWP)
Scale	National (recently)	National	Regional	National	Regional
Year initiated	2011	2011	2015	1998	2002
Number of members	130	70[1]	170	3059[2]	2091[3]
Size - Fraction of cultivated land	4.3% of total area under vine in South Australia	-	28% of Alentejo[4]	-	67% of Statewide acres
Size - Fraction of producers	35% of winegrowers and 40% of vineyards in McLaren Vale	-	-	Ca 75% of winegrowers	-
Size - Fraction of production	65% of total grape crush in McLaren Vale, 5% of South Australia	95% of total bottled export	-	95% of all South African produced wine	79% of Statewide cases

[1] Amount of certified wineries, i.e. not equal to amount of members. Another two are in the process of certification by the time of writing.

[2] 2641 vineyards, 418 wineries

[3] 1616 vineyards, 475 wineries

[4] Personal communication, Respondent 3

Australia - Sustainable Australia Winegrowing

Australia currently has three different third party certification schemes that vineyards and/or wineries can become certified under. Sustainable Australia Winegrowing (SAW) is one of them, together with 'Freshcare Environmental Viticulture/Winery' and ISO14001. These are all programs that are approved by the national sustainability program of the Australian wine industry – 'Entwine', which acts as an umbrella organization for sustainable wine production in Australia. The national sustainability program has two main membership categories available: Member and Certified Member. To be a member entails requirements on reporting business metrics as set out by Entwine, as well as participation in an Entwine-approved certification program, including a self-assessment. To be a certified member one also has to report on the same Entwine business metrics, but also participate in one of the Entwine-approved certification programs, including a third-party audit. The business metrics are reported to the Australian Wine Research Institute (AWRI), which is the Australian grape and wine industry's own research organization (the system structure is illustrated in Figure 2-2). The choice of SAW as case study object is made based on access of information as well as level of comparability to the other sustainability programs studied.

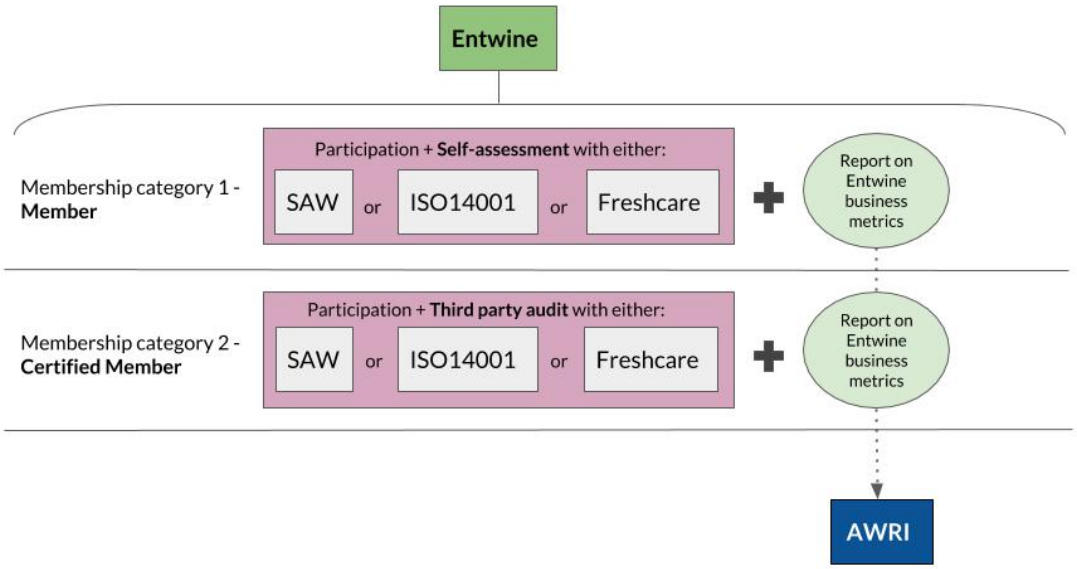

Figure 2-2: Depiction of the Australian wine industry's structure of sustainability programs. Adopted from illustration by AWRI (2016).

SAW is a voluntary sustainability program that stems from the McLaren Vale region in South Australia, which was initiated by the McLaren Vale Grape Wine and Tourism Association (MVGWTA) already in the early 2000's (SAW, 2017a). By the time MVGWTA was working on several initiatives within the industry, with the objective to improve the performance and sustainability of the region in terms of viticultural practices, fruit quality and regional economic strength. The initiatives ranged from seminars and workshops, research trials and a series of codes of best practice (covering areas such as pests, soil, water and biodiversity management). Together with extensive input from local growers and winemakers, these initiatives together became the foundation of the so-called Generational Farming Program formed in 2009, which later was to become SAW, with the purpose of promoting viticultural best practice and track results of wine producers (Santiago-Brown et al., 2014a). The program already by then included a Workbook that producers could use for self-evaluation, and had taken much inspiration in terms of content and design from the Californian initiatives Lodi

Growers and CSWA and their Workbooks (Santiago-Brown et al., 2014a). The program underwent some great changes in 2010 when a PhD student was hired, as her experience and findings from research on sustainability within the wine industry came to influence the MVGWTA and the regional work on sustainability assessment significantly (SAW, 2017a). Together with input from local growers a new, improved online version of the Generational Farming Program was launched the same year and became known as McLaren Vale Sustainable Winegrowing Australia. Three years later, five other regions were incorporated in the program, and the name was changed to Sustainable Australia Winegrowing (SAW). Last year (2017), MVGWTA undertook a full review of the program in where industry recommendations, legislation and best practices got incorporated to the current protocols. This was done together with several industry professionals and third party auditors in order to ensure continuous improvement and that the content was applicable to all regions in Australia, that it was auditable, and met critical criteria of Entwine-approved programs, as it now is a certification program under Entwine Australia (SAW, 2017a). Up to this point, the program only covers vineyards and represents 35% of winegrowers and 40% of vineyards in McLaren Vale (Flores, 2018). The program has 130 members, and in terms of geographical coverage, the area under vine that is part of the program make up 4.3% of vineyards in South Australia, and 44.1% of vine area in McLaren Vale (SAW, 2017a).

Chile – The National Sustainability Code

Wines of Chile (or 'Vinos de Chile), is a national non-profit organization with extensive domestic reach, representing more than 95% of bottled wine exports in 2009 (Santiago-Brown, 2014). As part of the Strategic Plan 2020 of Vinos de Chile, the national vitivinicultural sustainability program and its 'Sustainability Code' was developed with the objective of strengthening the sustainability of the domestic wine sector. It was developed by the Technological Consortium (the "technical arm" of the industry), industry representatives and University of Talca, and got launched in 2011 (International Trade Centre, 2011; Santiago-Brown et al., 2014a). The so-called 'Sustainability Code' is a voluntary tool acts as the foundation for the Vinos de Chile's sustainability work, and is divided into three different areas: Green (vineyard), Red (winery) and Orange (social). Initially, only the Green area was part of the Sustainability Code, but the consecutive year the other two areas were added (Santiago-Brown et al., 2014a; Vinos de Chile, 2012). Requirements in the Green area mainly revolves around resource management, such as agrochemicals, energy and water for irrigation; soil and pest management; staff training and waste management, while the Red area more focuses on waste reduction and recycling, energy savings, water management and prevention of contamination. Lastly the requirements in the Orange area have to do with ethics at work, the environment and working life quality among staff. In the different areas of compliance, some of the points are considered 'critical', while others are not (Vinos de Chile, 2013).

Similar to 'Entwine', the Australian national umbrella organization for vitivinicultural sustainability, the NSC consist of two membership categories – Level 1, which entails training and education, and Level 2, in where members are certified (Santiago-Brown et al., 2014a). Again, similar to Entwine, the NSC has different certifying bodies that the members can choose freely from, which are all internationally recognized certification bodies accredited by Vinos de Chile. Rather than certifying an end product, Vinos de Chile certifies the sustainable management of wineries, which allows them to carry the 'Certified Sustainable Wine of Chile' seal on their bottles (Vinos de Chile, 2012). At time of writing, the sustainability program has 70 certified members, and two under the process of becoming certified.

Portugal – Wines of Alentejo Sustainability Program

The Wines of Alentejo Sustainability Program (WASP) is a voluntary sustainability initiative for the winemakers of the Portuguese region of Alentejo, established in 2015 (making it the

most recently created program of the studied case objects). It was created by the Alentejo Regional Vitivinicultural Commission (CVRA, hereafter), a privately owned institution tasked with ensuring the quality and safety of the commercial wines produced in the region. The WASP program sets out to deliver value to the wine sector of the region by addressing social, economic and environmental concerns, to strengthen the collaboration between wine growers and producers, and to provide education to disseminate contemporary knowledge on best practice in terms of sustainable wine production (Vinhos do Alentejo, 2018a). Wines with a certification of quality and origin from the CVRA (DOC Alentejo) make up about a fourth of total certified wine in Portugal, and those producers whose wines bear this CVRA stamp of approval, as well as the farmers who produce their grapes, are invited to enroll in the sustainability program (Vinhos do Alentejo, 2016).

The sustainability program covers both vineyards and wineries, and their Sustainability self-assessment 'Workbook' is divided into three distinct sections – Vineyard; Winery; and Vineyard & Winery, which is used according to the nature of production amongst members (Vinhos do Alentejo, 2018a). Currently the program has 170 members, and is continuously growing. As WASP is yet in its infant stages, there is still no third party certification mechanism in place. However, WASP Management estimates that members will have the option of becoming 'certified sustainable' by an accredited third party certification body by 2020 (Angel et al., 2018).

South Africa – Integrated Production of Wine

The sustainability work in the South African wine industry dates back to 1998, when the voluntary scheme of environmental sustainability called 'Integrated Production of Wines' (IPW) was established by the South African wine industry (WOSA, n.d.a), and in the same year was promulgated by a South African governmental Act (Santiago-Brown et al., 2014a). The IPW is managed by the Wines and Spirit Board (WSB), and is one of three national programs that together make up the sustainability work of wine production in South Africa. The other two are the 'Biodiversity and Wine Initiative' (BWI) and the Wine and Agricultural Industry Ethical Trade Association (WIETA) Code (Santiago-Brown et al., 2014a). BWI mainly deals with the conservation of the Cape Floral Kingdom (CFK) - the richest and smallest plant kingdom on the planet in where 95% of South Australian vineyards occur (Flores, 2018), while WIETA revolves around fair labor practices and ethics. In order to manage existing sustainability initiatives, Sustainable Wine South Africa (SWSA) was formed, which is an alliance between the WSB, the IPW scheme and Wines of South Africa (WOSA) (WOSA, n.d.b).

Today the scheme covers 3059 members, or about 75% of South African wine growers (Flores, 2018). Year 2000 was the first year under which vintage could become certified under the IPW scheme and now almost 95% of all South African wines are certified under this scheme, carrying the so-called 'Integrity and Sustainability' seal (WOSA, n.d.a; Flores, 2018), despite its voluntary nature (Santiago-Brown et al., 2014a). Bottles holding this seal ensure both origin of grapes and sustainable practice in line with the IPW requirements through the whole production line, meaning that wineries, as well as 100% of the grapes used to produce the wine need to be compliant to the guidelines (Santiago-Brown, 2014a). The scheme consists of two main documents – the guidelines and the manual. The guidelines are in principle a set of recommendations of necessary actions, as well as minimum standards for compliance to the scheme, while the manual is more of a practical document focusing on how the guidelines can be implemented and how the self-assessment should be completed in order to facilitate further third party auditing and WSB certification (Santiago-Brown, 2014). Compliance with IPW scheme can be divided into different activities of wine production (farm, winery and bottling) – either separately or in combination. (IPW, n.d.).

California, USA - Sustainable Winegrowing Program

The Sustainable Winegrowing Program (SWP, hereafter) of the California Sustainable Winegrowing Alliance (CSWA) was developed in 2001 by the two industry trade organizations The Wine Institute (representing wineries) and the California Association of Winegrape Growers (representing growers), in order to promote continuous improvement in the adoption of sustainable practices within the industry (California Sustainable Winegrowing Alliance et al., 2012). The non-profit organization CSWA was formed two years after the SWP was launched, with the purpose of administrating and implementing the SWP. The 'Workbook' of the program - the 3rd, and latest, edition released in 2013, is a voluntary self-assessment tool for vintners and growers and acts as the foundation of the program (California Sustainable Winegrowing Alliance, 2018). It consists of a set of assessment chapters covering both vineyard and wineries, with the mission to assist wine producers with assessing the degree of sustainability of their current practices; to identify areas of excellence as well as areas where improvements can be made; and to develop action plans to increase an operation's sustainability (California Sustainable WA et al., 2012). In 2010, CSWA launched the third-party certification program called Certified California Sustainable Winegrowing (CCSW), or simply 'Certified Sustainable', with the aim to increase the sustainability of regional wine industry through creating a verification process for vineyards and wineries (CSWA et al., 2012; Santiago-Brown et al., 2014a).

In 2017, CSWA updated the program by enabling the use of a new seal on wine labels. This seal acts as a proof for that wine was made in a winery with 85% or more of its winegrapes coming from certified vineyards, and 100% of grapes from California (California Sustainable Winegrowing Alliance, 2017). CSWA is only one of several other initiatives dedicated to sustainable, organic and/or biodynamic production of wine in the state of California. However, with its 127 certified wineries and 1099 certified vineyards, and 74% of total wine cases produced in California being made by vineyards carrying the Certified Sustainable label, it is one of the largest and most important sustainability programs of the region (California Sustainable Winegrowing Alliance, 2017; Santiago-Brown et al., 2014a).

Up until this point, wine sustainability programs have been discussed in a general context of sustainability. As this research has a specific focus on water management within the wine industry, the consequent sections deals with water issues applicable to wine production, as well as findings on quantifications of water use in the countries under scrutiny, in a search for country and industry benchmarks for water use through the production of wine.

2.3 Water and vitiviniculture: An overview

Being a fundamental element for life and an irreplaceable resource, freshwater and its availability is a concern for everyone on this planet. Over recent years, the issue of water scarcity has become more widespread as the effects of climate change are becoming more pronounced and the freshwater demand from an increasing global population is growing. The latest assessment report from the Intergovernmental Panel on Climate Change (IPCC) affirmed that the supply and availability of freshwater will become an increasing problem, especially in dry regions and in rural areas, negatively impacting crop yields and threatening food security (IPCC, 2014). The Water Footprint Network estimate that by 2050, 52% of the (by then projected), 9.7 billion people will live in regions under water stress and 37 countries will be under 'extreme water stress', meaning that they consume more than 80% of their total water supply available each year (Water Footprint Network, n.d.).

Limited water supply is already being felt in many parts of the world. The World Health Organization (2018) estimated that in 2015, 844 million people lacked access to basic drinking

services. More recently, South African residents have experienced dramatic restrictions on water use due to the severe droughts the country has suffered during the last years, coupled with poor water management and a growing freshwater demand (EESI, 2018). With this said, the threat of water scarcity is more serious than ever before. Thus there is a great need to gain better insight into how water is managed and what can be done to improve current ways of water management across all sectors and use areas around the world. The agricultural sector is of particular importance, as it is the single largest user of water in the world – withdrawing about 70% of total freshwater globally and consuming an estimated 80-90% of total freshwater (Reytar et al., 2014; The World Bank, 2017). With the projected population growth it is estimated that agricultural production will have to increase by roughly 50%, and that water withdrawals will be 15% more than of today, in order to sustain a healthy population (The World Bank, 2017). At the same time, the OECD reports that farmers will have to rely on significantly less freshwater resources in the future due to rising temperatures and extreme weather events occurring more often, but also as a consequence of increased competition between growing industries and a denser urban population. Agricultural production is moreover projected to be negatively impacted by reduced water quality, primarily through projected increase in polluting activities and through changes in water supply and rising sea levels, that will cause saltwater to intrude the soils, leading to salination of land area (OECD, 2016). As ecosystems are directly impacted by water availability, inefficient use of water for crop production may in the long run lead to aquifer depletion, reduced river flows and wildlife habitats degradation (FAO, 2015). Having this said, it is of critical importance that we handle our freshwater stocks in a sustainable manner, especially within the agricultural sector, if we are to have functioning ecosystems, and consequently, societies.

As most industries within the agricultural sector, the wine industry is a large user of water. The average water footprint of a bottle of wine is estimated to around 610L (Mekonnen and Hoekstra, 2011), which is relatively large compared to several other beverages such as tea and beer (Mekonnen & Hoekstra, 2011; Hoekstra & The Water Footprint Network, 2017), making it an interesting product to investigate for potential ways of reduction in water use. With a global wine production of about 35.6 billion wine bottles (in 2016), annual water use of the wine industry totals some 22 000 billion liters of water (data converted from OIV, 2017a). Seeking improved water efficiencies in the wine industry is of special importance as the majority of the principal viticultural areas already occur in semi-arid regions (Flexas et al. 2010) which, as mentioned, are projected to become even drier with increasing effects of global warming (IPCC, 2014). Moreover, with a growing middle class expected to reach 1.6 billion people by 2030 (Miller & Spoolman, 2012), demand of wine (which can be considered somewhat of an indulgence product), could be expected to increase, again speaking for the importance of reducing water use within the industry.

2.3.1 Water use in wine production

For reasons to facilitate understanding of terminology and the components of the wine production chain discussed throughout this paper, a very brief description of the main processes of wine production is given below, along with a simplified sketch in Figure 2-3.

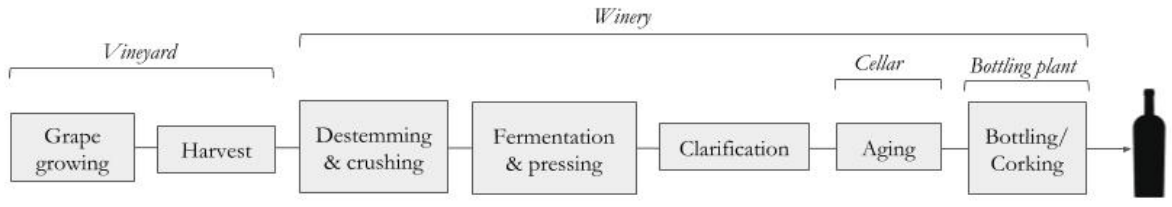

Figure 2-3: Simplified sketch over the different steps in the wine making process. Adapted by Galitsky et al. 2005.

Although numerous variations to the way grapes are processed exist (depending on type of grapes, desired product characteristics, winery design and harvesting conditions), the fundamental steps (as depicted in the figure) of wine production remain the same (Galitsky et al., 2005). Once ripe, grapes are harvested and brought from the vineyards to the wineries for processing. The first step is to remove leaves and stems from the grapes, and once this is done, mechanical crushes trod the grapes into a must, i.e. grape juice, containing skins, seeds, and solids from the grapes (Laurel Gray, 2014). For white wines, pressing is done instantly after crushing to avoid coloring or addition of unwanted tannins, as solids, skins and seeds are separated from the juice, while for red wines, pressing of the must occur after the must has fermented, as the skins and pulp add to its red color (Galitsky et al., 2005). The presses are cleaned with water at the end of the day, or between pressing of white and red wines. The fermentation process is where yeasts convert sugars into alcohol, carbon dioxide and heat, which can take between a week to over a month depending on desired wine properties (Galitsky et al., 2005; Laurel Gray, 2014). After fermentation, the wine goes through a process called clarification. Here the solids (i.e. dead yeast cells, tannins, and proteins) are removed using different methods such as filtering, fining or racking, depending on winery and wine, and then poured into vessel such as an oak barrel or a stainless steel tank. The final stage of the wine making process is aging and bottling. Some wines are bottled almost immediately after clarification; while other wines are aged for very long periods in order to add flavors from the vessel it sits in, before being bottled (Galitsky et al. 2005; Laurel Gray, 2014).

Water is a highly central resource in the production of wine – both at the vineyard and in the winery. Looking to Water Footprints of wine (discussed in 2.2.2), the vast majority (about 80-90%) of the water use connected to wine production is assigned to grape cultivation (Herath et al., 2013; Bonamente et al., 2016). This is explained by that the water "consumed" by the crop does not only cover directly applied water from irrigation, but also (mainly) the amount of rainwater lost through evapotranspiration due to crop water needs, which, without the presence of the crop is assumed to have replenished ground water sources (Mekonnen & Hoekstra, 2011). While water input at vineyards is primarily linked to irrigation, in some regions growers are actually able to "dry farm", i.e. not irrigate the vines at all. This is possible if there is enough natural supply of water, and if sufficient soil moisture can be retained through the dry season (typically using different agricultural practices such as canopy management cover crops and different means of root zone charging) (Lodi Growers, 2018; Lambert, 2015).

In the wineries on the other hand, the central water demanding activities are cleaning and washing the equipment as well as the facilities that are part of the different production stages (such as fermentation tanks and barrels, bottling lines, cellars, and the press area) (Galitsky et al., 2005). According to the same source, other use areas of water include humidification; which is typically used both in the cellars and the barrel storage area to remain cooler temperatures and, as with any building; some of the water use is also linked to toilets and sinks etc. Wine production also gives rise to a whole lot of wastewater, mainly polluted by organic compounds through the different stages of production, such as from de-stemming, pressing and fermentation (Conradie et al., 2014). Some wineries are treating the wastewater originating from their production in order to save water and use it e.g. for irrigation or fire protection purposes, while others send their wastewater to municipal treatment plants (Galitsky et al., 2005).

Looking to a sustainability perspective of water use in the wine industry, Medrano et al. (2015), considers the industry to be under serious threat. This claim is based on that total water consumption of vineyards typically exceeds the annual average precipitation in most viticultural areas; on that more than 60% of viticultural areas already occur in semi-arid areas

(Flexas et al., 2010); as well as on the expected rise in irrigation needs is likely as a response to the projected rise in global average temperatures as a consequence of climate change (Medrano et al., 2015). For these reasons, the same article identified water as the most important environmental concern with regards to the sustainability of wine production and concluded that there is a great need for wider efforts in the field of water efficiency in the wine industry in order to secure the survival of vineyards in drier regions in the near future.

Climate change is not only projected to bring about higher average temperatures and more extreme weather events, but will, in rough terms, likely contribute to drier conditions where water is already scarce, and wetter in areas which already receives large quantities of precipitation (IPCC, 2014). Apart from direct impacts for the wine industry in terms of freshwater availability, climate change affects the wine industry in many other ways, some of which are briefly introduced in Box 1 below.

Box 1: Vitiviniculture and climate change

Wine producers are impacted by the changes in climate in a number of ways. Hotter temperatures in the growing season is a manifold problem, as it pushes the date of harvest back to a hotter month, which due to global warming is (and will become) hotter than current average temperatures during this time of the year. This not only risks to reduce the quality of the grapes as the biochemistry and flavor molecules of the grapes are altered, but will also mean logistical problems for the wine producers as the time period between harvest of early and late grape varieties will be reduced. More frequent occurrence of extreme weather events such as drought, frost and bushfires, is another general threat to grape growers (Anderson et al. 2008). The same article concludes that vineyards might have to relocate to cooler, or higher-altitude regions as a response to the changing weather patterns, and that the number of suitable places for growing grapevines will diminish over time (Anderson et al., 2008). The article has a focus on Australia, but as the studied countries/regions used in this study are in similar climatic zones, the same arguments apply here too.

Because of these reasons, the wine industry is already doing a lot in order to save water (which will be further discussed in section 2.3). However, the scope of environmental issues connected to the production of wine remains poorly understood (Flores, 2018; Christ and Burritt, 2013), and, especially in terms of water use, better quantifications of its environmental impact is needed (Costa et al. 2016).

2.3.2 Indicators and benchmarks for water use

In almost any given company, industry or organization, internal and external stakeholders have a strong interest to measure performance of the entity under concern. For these reasons, indicators across different areas are used for measuring and communicating meaningful results of company performance, usually in order to support decision-making (Yli-Viikari, 2009). Indicator results are often used to study performance over time and, if harmonized, these results can assist with benchmarking across companies or programs and identify best practice (Merli et al., 2018). In the context of this research, many wine sustainability programs use indicators for purposes of creating benchmarks for program participants, for setting regional targets, tracking development over time or for formulating certification criteria (Santiago-Brown et al., 2015). A number of studies have been devoted to investigate, compare or suggest indicator use among sustainability programs, especially relating to environmental

performance (Santiago-Brown et al., 2015; Merli et al., 2018; Rosner et al., 2015; Corbo et al., 2014). These studies have all identified a vast array of indicators, and clearly demonstrate that no standard set of environmental, economic or social indicators exist in the wine industry. Santiago-Brown et al. (2015) interviewed more than eighty practitioners and experts within the field, and found 171 different indicators, just in terms of environmental aspects, while Rosner et al. (2015) identified nearly one hundred different types of sustainability assessments relating to water use in the wine production chain.

How to determine the 'best' or most 'meaningful' indicators however remains an important challenge (which the large amount of identified indicators gives an idea of), partly due to the interconnected nature of sustainability aspects - making isolation of certain parameters for explanation of total effects difficult (Santiago-Brown et al., 2015). Some approach this by conducting life-cycle assessments (LCA) in order to identify areas of high environmental impact (Merli et al., 2018), assisting decisions on indicator needs. While LCAs are some of the most commonly used and complete environmental assessment methods there is (Christ & Burritt, 2013), the method of life-cycle analyses in the scope of the agrarian practices tend to vary, as processes are not easily standardized (Merli et al., 2018; Rugani et al, 2013). This is also seen in the wine industry, in where many of LCA studies made on wine production tend to not use different system boundaries for such assessments (Ferrara & De Feo, 2018). This phenomenon further complicates identification of sustainability indicators, which often make single use indicators such as Water or Carbon Footprint more feasible and suitable to use (Merli et al., 2018).

Finding commonly accepted sustainability indicators is further complicated by the fact that there is no universally accepted definition of sustainability in the wine sector, as concluded in a study by Santiago-Brown et al. (2014b). However, some studies have tried to address this issue, including the study by Santiago-Brown et al. (2015) mentioned above, in where the 171 identified indicators were merged into 26 different environmental indicators and ranked by the interviewees based on perceived importance. According to their results, the indicator 'water use optimization' was considered the second most important one, after soil health, in order to measure environmental business performance. Other studies investigated what environmental aspects were considered most critical in the context of wine production by making extensive literature reviews, and found that water consumption (for irrigation and wine-making), as well as water quality, were identified as key environmental issues, especially in areas where freshwater is a scarce resource (Merli et al., 2018; Christ & Burritt, 2013) – further signifying the need for indicators for these areas. Yet, even if indicators for water use in vitiviniculture are universally agreed upon, there is still an issue of comparing performance across regions or countries, as climatic differences affect water availability and the use rate of water, thus impeding creation of meaningful common benchmarks for wine growers and producers (Christ & Burritt, 2013; Herath et al. 2013).

While several studies have stressed the criticality of efficient water use in the context of wine grape growing and wine making, no study has been identified specific activities or operations that should be prioritized (or considered as superior) for assessment in order to indicate overall performance on water management at the vineyards and the wineries, as far as the author is aware. Merli and co-authors found that most wineries use an indicator of annual water use per unit of product (typically measured in cubic meters per kg grapes or L wine), but the units used for this indicator tend to vary between both wineries and sustainability assessment frameworks (Merli et al., 2018). However, the online platform 'Water & Wine' do indicate some areas of key performance indicators (KPIs) for winery operations, such as barrel hydration and cleaning & sanitation of barrels/filters/tanks/hoses and presses/crushers

(Water & Wine, n.d.), largely agreeing with the recommendations on winery water management in Galitsky et al. (2005).

Thus, by looking into what different areas in terms of water use and management that members are being assessed on within the investigated sustainability programs, important insights into water use assessment are provided through this research.

2.3.3 Water Footprint

Before presenting existing estimates on water use in the respective countries under concern, and introducing current efforts to address sustainability concerns in the wine industry, it is considered necessary to give the reader a brief background into how water use quantities are estimated and how different forms of water use are linked to the production of wine.

For reasons to estimate how much freshwater actually is being used for the production of a certain product, the concept of a "Water Footprint" (WF, hereafter) was introduced by Hoekstra in the early 2000's and has been further developed over time (Mekonnen & Hoekstra, 2011; Hoekstra & Chapagain, 2008). The WF, also known as "virtual water content", is an indicator of direct and indirect appropriation of freshwater resources expressed in water volume per unit of product, and considers water consumption and pollution in all the steps of the production chain for the product under consideration (Hoekstra, 2017). The total WF is the sum of the so-called "consumptive WF" - which consists of the "green" and the "blue" WF, and the "degradative WF" - also called the "grey" WF (Hoekstra, 2017). The *green* WF refers to the amount of rainwater being consumed through crop evapotranspiration; the *blue* WF refers to the volume of surface and groundwater consumed as a result of the production of a product; and the *grey* WF is an estimate of how much water is needed in order to dilute the amount of discharged pollutants into surrounding freshwater bodies to ambient water quality standards (Mekonnen & Hoekstra, 2011). The *grey* WF is important to take into account, considering that not only freshwater *consumption* may lead to water scarcity, but *pollution* further increases the competition for freshwater resources and thus plays an important role too in terms of estimations of water availability (UNDP, 2006).

Many studies have been devoted to estimate WFs of different kinds of wines around the world (e.g. Bonamente et al., 2016; Herath et al., 2013; Lamastra et al., 2014; Quinteiro et al., 2014). Although the estimates vary between wines, regions and studies; it can generally be said that for wine, the green WF constitutes the vast majority of the total WF. To get a sense of the distribution of the different types of WFs, Lamastra et al. (2014) calculated the WF for six different vineyards in Italy, belonging to the same winery, and found an average green WF of 77%, a grey WF of 17% and a blue WF of 7%, using the methodology proposed by the Water Footprint Network, (which is based on the work of Hoekstra, who also took part in founding the organization) (Water Footprint Network, n.d.). The significance of the green water footprint was also confirmed by Bonamente et al., who in 2015 reported a global average water footprint for a bottle of wine to be ca 652L, and that the green water footprint make up between 85%-99% of the total water footprint.

While the WF methodology adopted by the Water Footprint Network have been widely used, and by now even has been referred to as the "classical" method (in Lamastra et al., 2014) - other methods exist, and it appears there is still no consensus on what can be considered the best method for estimating a water footprint. Several studies have been devoted to improve the estimations of WFs using other methodological approaches - even within the wine sector (e.g. Lamastra et al., 2014; Bonamente et al., 2015). In a literature review made by Ferrara & De Feo (2018) looking into use of environmental assessment methods within the wine sector, it was found that for calculating WFs of a wine bottle, not only was the Water Footprint

Network method used among the studied sources; but also LCA-based methods such as 'Freshwater ecosystem impact' and 'Freshwater depletion', as well as the 'hydrological water balance method'. More recently, the International Organization for Standardization (ISO) recognized the issue of varying methodological approaches for estimating WFs, and developed an international standard, called ISO 14046: "Environmental management - Water footprint - Principles, requirements and guidelines", which is designed to aid actors within industry, research, and other stakeholders to estimate water footprints, taking on a life cycle perspective (Costa et al., 2016).

As WF reporting yet is a relatively new phenomenon and, as demonstrated, can be estimated using different methods, careful attention to methodological approach should be taken when comparing water footprints of any products, including wine – which is recognized in this research.

2.3.4 Water use estimates from literature

Below a summary of all the quantifications found on water use in connection to wine production in the countries within the scope of this research are presented, in order to give the reader an idea of current estimates, and how they vary. To facilitate comparison, estimates have been harmonized to the same unit (L consumed water/L produced wine) wherever possible, in Table 2-2 below. In one case, estimates from another country are provided for comparison.

Table 2-2: Overview of water use estimates found in literature.

Author	Water-to-wine ratio (L water/L wine)	Scope	Country
Amienyo, Camilleri & Azapagic (2014)	484:1	Vineyard to end-of-life (cradle to grave)	Australia
Kumar et al. (2009)	0.53:1 - 10.7:1	Winery	Australia
Martins et al. (2018)	1.6:1 - 4.9:1	Winery	Portugal
Engel et al. 2015	1.2:1 - 14.4:1	Winery	Portugal
Engel et al. 2015	88:1 - 264:1	Vineyard	Portugal
Quintero et al. (2014)	499.3:1	Vineyard + Winery (Green + blue WF)	Portugal
Water & Wine (n.d.)	3:1-10:1	Winery	USA
Steenwerth et al. (2015)	141-165:1 *(L/kg grapes)	Vineyard	USA
Gabzdylova et al. (2009)	5:1	Winery	New Zealand

Looking to Australia, Kumar et al. (2009) made a comprehensive study on water use and waste water generation among Australian wineries and found best practice to be 0.4L water use per 0.75L bottle of produced wine; averages to be 2.0L/bottle of wine; while the highest values of water use were reported to be 8.0L water/bottle - indicating large inefficiencies in some wineries. Amienyo, Camilleri & Azapagic (2014) conducted an LCA study on Australian wines consumed in the UK and found a water footprint of 363L water/bottle of wine, using the system boundaries cradle-to-grave.

Martins et al. (2018) instead look at water use in Portuguese wineries through conducting an LCA study, taking wine making, bottling and packaging activities into account, while excluding vineyard operations, distribution and use phases, and found an average water use of 1.6L, respectively 4.9L water/bottle of wine produced for two different Portuguese wines.

Quinteiro et al., (2014) used a larger scope of their LCA study of two different Portuguese wines, where both the vineyard and the winery operations were included, and the end-point, or 'gate' was instead after the bottling facility, when the wine is ready for distribution. This study found an average green water footprint of 369.9L/bottle of wine, and a blue footprint of 4.6L/bottle. These footprints are significantly lower than the global average for green and blue water footprints (455L respectively 103L water/bottle of wine) estimated by Mekonnen and Hoekstra (2011). However, as pointed out by the authors, the region inspected receives a lot more precipitation than the national averages, and wine growers here do not have to irrigate their vines, probably resulting in a significantly lower footprint than for Portugal as a country (Quinteiro et al., 2014). Another study conducted in Portugal, specifically devoted to the development of the WASP program, found that estimates for water use at vineyards of Alentejo ranged from 88-264L of freshwater per liter produced wine, while winery freshwater use ranged between 1.2-14.4L per liter of produced wine, based on personal communication with winegrowers and vintners in the region (Engel et al., 2015)[1].

In terms of estimates on water use for wines produced in the USA, one LCA study conducted in the Californian wine districts Lodi and Napa was found, investigating twelve different production scenarios, with varying degrees of irrigation, fertilizer use and different farming practices (cover crops, tillage etc.). The amount of greenhouse gases, energy as well as water used over the annual cycle for wine grape production was estimated, with a starting point in raw material extraction for production of vineyard inputs, and an end point at the delivery of grapes to the winery gate. The results varied largely between the two regions, with a water use of 265m^3 water/ton grapes in Napa and 141 m^3 water/ton grapes in Lodi (Steenwerth et al., 2015). Of the twelve scenarios, the average water use was around 180 m^3 per ton grapes. The estimated water use was based on directly applied water to wine grapes for irrigation and delivery of liquid fertilizer, as well as on the water consumed in the life cycle of inputs to the system. Water extracted from surface and groundwater sources were included in the calculation, but precipitation was not considered. An American online platform called 'Water & Wine' report and industry benchmark for water-to-wine ratio of 3:1 – 10:1 on their website in a template for estimating individual wine producers water use in wineries (Water & Wine, n.d.).

No other water use estimates for wine production in the countries or regions studied in this research could be obtained among academic papers or other literature. However, for comparison, a study on New Zealand's wine production in relation to water consumption reported an approximate water use of 5L per L produced wine in wineries, and everything between 210L to 900L of water per plant per year in the vineyards (not included in the table due to unit differences), depending on regional variances in e.g. soil and climatic conditions (Gabzdylova et al., 2009).

Although great variations in quantifications, as well as large inconsistencies in terms of methodology and scope for these estimates, an indication on range of water use in relation to vineyard and winery activities discern from the numbers provided. These are the only estimates found from the relevant countries, and are intended to act as benchmarks for comparison with findings from the respective sustainability programs under investigation.

[1] Paper available on request.

3 Methodology

3.1 Research design

This research primarily builds on five different case studies, or in-depth analyses, of five vitivinicultural sustainability programs in where program design; assessment criteria; member support and performance; sources of program content; and (by program representatives) perceived drivers and barriers for greater adaption of sustainability practices (including efficient water management) was studied. Information on these issues was obtained both from literature and from primary sources, which is further described in the sections below.

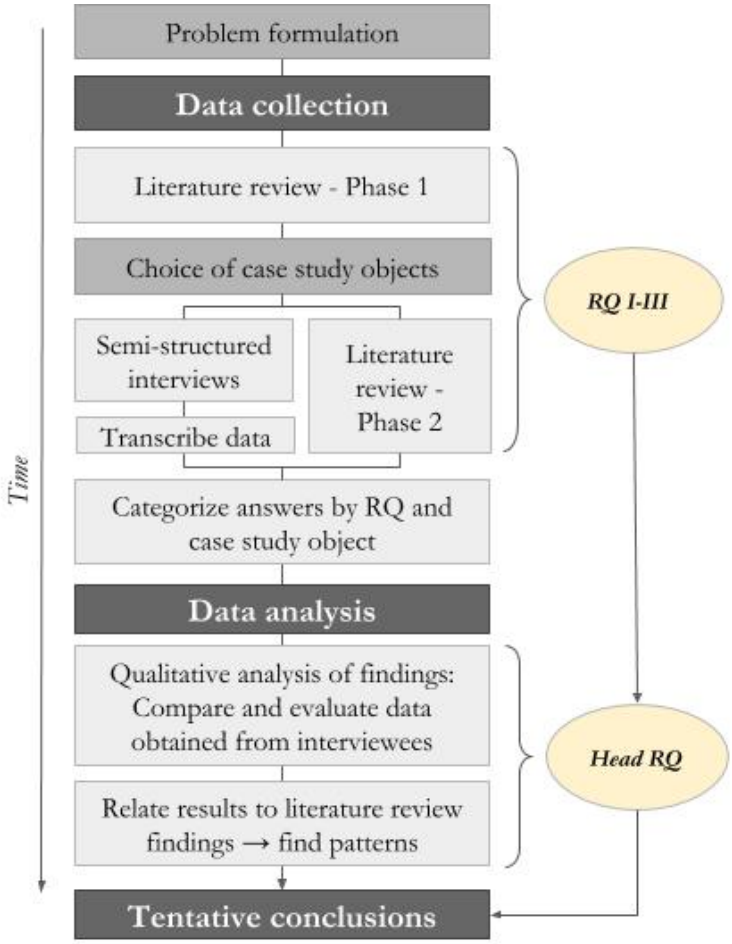

Figure 3-1: Simplified structure of research approach.

The collective findings from literature and interviews were categorized into the respective program and research questions to facilitate comparison of the different case study objects. Through a qualitative analysis of the collected data, comparing differences and similarities in relation to the different research questions (hereafter *RQs*), emerging patterns among the case study objects were identified. The method used for data analysis is described in detail in section 3.3. The emerging patterns from the qualitative analysis were later compared (in applicable cases) and related to findings and estimates presented in the literature review chapter, in order to investigate coherence and relevance of these findings compared to existing knowledge in the field of sustainable vitiviniculture, and to draw tentative conclusions based on the research conducted.

The research questions were designed so that they should address and align with the fourfold research aims; in where the first three stated aims are reflected in *RQI-III*, while the fourth aim is addressed in the overarching, or 'head' research question, using input from *RQI-III*. A simplification of the research approach used in this thesis is depicted in Figure 3-1 above - a structure which is largely inspired by the model for an inductive, qualitative study as proposed by Creswell (2014). As this figure also illustrates; research questions *I-III* were addressed in the data collection phase, while the overarching, or head, research question was addressed in the analytical part of the discussion, which in turn supported the tentative conclusions drawn in this research.

With limited prior insights into how sustainability programs within the wine industry are working with issues relating to water management, and how they interact with program members - an inductive, or exploratory, approach was used throughout the research. Thus, no hypotheses for the outcome of the respective research questions addressed in this study have been formulated, and no pre-defined theoretical framework was deemed apt or necessary for the purposes of this research.

3.2 Data Collection

3.2.1 Literature Review

This paper addressed the stated research questions set out in section 1.2 partly through conducting a thorough literature review within the field of vitivinicultural sustainability programs, with a focus on water management within these. The conducted literature review can be divided into two distinct phases. First, general knowledge and context to the topic was created by collecting background information relevant for the study, which also guided the decision on case study objects suitable for this research. This included reading up on existing studies on wine sustainability programs around the world; the issues faced by the wine industry in relation to water use; how sustainability programs currently are working in order to address these issues; previously identified drivers for adoption of sustainable behavior; estimates on water use for wine production; use of indicators etc. The final pick of case study objects for this study was based on the following criteria;

- Presence of a relatively mature vitivinicultural sustainability program
- Access to information
- Region/country covered by the sustainability program should be under medium or high water stress
- Region/country covered by the sustainability program should have a relatively large production of wine
- Chosen regions/countries should have a good spread across continents

Once the case study objects were chosen, the second phase of the literature review was initiated. This involved reading up in detail on the structure, key mechanisms, documents and their content (with a special focus on water, in cases where such data could be obtained) for the respective programs. A more detailed overview of the topics covered in the literature review is given in Table 3-1, however this list is non-exhaustive. It can generally be said that the second phase of the literature review was largely dedicated to address RQs *I-III*, and complement the gaps in knowledge that could not be gained from the interviews.

Table 3-1: Overview of topics covered in the literature review.

First phase	Second phase
Global situation on wine sustainability programs - history and current situation (+above criteria)	Scope, design, structure, key mechanism and content of the respective sustainability programs
Wine production and its water demanding activities	Assessment criteria on water use
Current situation and future predictions of water availability and its relation to vitiviniculture	Reported performance from the respective programs (if available)
Quantitative estimates on water use (WFs/LCAs etc.)	Program material supporting members with greater uptake

in wine production within relevant countries	of water saving practices
Use of indicators to assess water management within vitivinicultural sustainability programs	Reported barriers & drivers for uptake of sustainability practices in the context of wine industry (in academia)
Best practices on water management	Existing theories on successful means of adaption of sustainable behavior

For both phases of the literature review, databases such as Scopus and EBSCO were used to a large extent, using Lund University's search tool for academic literature 'LUBsearch' and the search engines Google Scholar and Google. However, it can be generally said that the initial phase was more relying on academic sources, while the second phase more involved studying grey literature, websites of the sustainability programs and their internal documents, such as sustainability and annual reports, workbooks, sustainability codes and performance summaries from the respective sustainability programs and their members; reports from wine industry branch organizations (e.g. OIV, FIVS, Wine & Water), and other actors within the wine industry (e.g. Entwine, The Wine Institute, Lodi Growers etc.). The literature review also used sources from multilateral agencies and environmental think tanks (e.g. the World Resources Institute and IPCC). Experts within academia were consulted for obtaining further data sources relevant to the research.

The key search terms/concepts that have guided data collection included, but were not limited to: 'Viti(vini)cultural sustainability programs'; 'Water management + wine industry'; 'Drivers and barriers for sustainable wine production'; 'Implementation of water saving practices vitiviniculture'; 'Vitiviniculture and climate change'; 'Water footprint of wine + Australia/Chile/Portugal/South Africa/USA'; 'Wastewater wine industry; 'Best practices/BAT water management + wineries/vineyards'; 'Measuring environmental performance wine industry/agriculture'; 'Comparison wine industry sustainability programs'; 'Environmental indicators for wine production' etc.

3.2.2 Interviews

Collection of primary data was made through interviews with key representatives from the respective sustainability programs selected for this study. The interviews were of semi-structured format with open-ended questions and typically lasted for approximately one hour. Information was primarily collected over the online software Skype, however in those cases in where interviewees were not available for an online interview, data was instead collected through email. In one case, all of the intended questions were not possible to cover during the given time of the Skype interview, thus answers for these questions were instead complemented over email. A complete list of the interviewees, their respective position and their means of communicating information is given in Table 3-2 below. The interview guide that was used for collecting primary data was designed to provide necessary insights in order to answer the research questions, and can be found in Appendix B. All the interviews were audio recorded after consent had been given by the interviewees, in order to enable posterior analysis of data.

Table 3-2: Overview of the persons interviewed and their position.

Country	Australia	Chile	Portugal	South Africa	USA (CA)
Framework	Sustainable Australia Winegrowing (SAW)	National Sustainability Code (NSC)	Wines of Alentejo Sustainability Program (WASP)	Integrated Production of Wine (IPW)	Sustainable Winegrowing Program (SWP)
Name of interviewee	Rachel Williams	Patricio Parra	João Barroso	Daniel Schiëtekat	Kate Venugopal
Reference key used in text	Respondent 1	Respondent 2	Respondent 3	Respondent 4	Respondent 5
Position/role	Grower Engagement, MVGWTA	Innovation & Development Manager, Vinos de Chile	Sustainability Manager, CVRA	Manager, Wine and Spirit Board	Communication Manager, CSWA
Means of communication	Email	Skype	Skype	Email	Skype & email

The interviewees were chosen based on their expected insights into performance, functioning and status of the sustainability program and its members; access to relevant resources regarding member data on water management; as well as on best practices regarding water management within the industry and the region. Contact details were obtained from the website of the respective sustainability initiatives, and in one case by one of the interviewees whom the author has cooperated with previously. The initial contact was made through email, in where the research project was introduced and an interview was requested. The email also contained a note that in case the recipient did not want to or could participate in an interview, a referral to another person well suited for the requested interview was requested. In most cases, reminder emails were sent out and oftentimes the author was referred to another person considered more apt for an interview.

3.3 Data analysis

To allow for analysis of the information obtained through the interviews, all the interviews were audio-recorded, after consent had been given by the interviewee. These recordings were manually transcribed and the answers were later thematically categorized based on their relation to the different research questions. Similar categorization was made of the findings collected from the literature review. Once categorized under related research question, subtopic and sustainability program, a qualitative analysis of the data was made (which has been proven a suitable method in a similar study (Santiago-Brown et al., 2014a)), looking for similarities and differences across programs in relation to the different *RQs*.

The patterns emerging from the qualitative analysis of the findings then helped supporting formulation of a set of tentative conclusions. These conclusions were then compared, in applicable cases, to similar studies, quantifications and existing topical knowledge (presented in the literature review) to investigate the coherence of these claims with previous findings.

The findings obtained for *RQ I-III* were then together used to draw conclusions and assist in answering the overarching *RQ* for this study, i.e.: '*How can vitivinicultural sustainability programs improve adoption of sustainable management of water resources among its members?'*. Again, answers to this question were also sought in academic articles and other secondary sources. How each of the *RQs* were addressed in order to support answering this question is detailed below.

Information in relation to *RQI* (on current program efforts for increased adoption of sustainable water management among members) was attained using slightly different sources and methods, due to the nature of the sub-questions. Answers for *RQIa*, looking into areas and means of which members are assessed on water management issues, could largely be obtained through consulting online sources such as websites of the respective case study objects. In those cases were sought data could not be obtained; information was requested in the interviews or through email. In order to enable a structured comparison of the case study objects, certain parameters of the assessment design of the respective programs were chosen to create an overview of their respective ways of assessing members on water management. These investigated parameters were chosen based on previous studies of similar character (Flores, 2018; Santiago-Brown et al., 2014a; Merli et al., 2018; Corbo et al., 2014) and on personal notions of the author of what was considered relevant for the purposes of this research. The chosen parameters were the following: presence of a "Workbook", a self-assessment system; performance differentiation; requirement on continuous improvement; third party validation; validation frequency; third party certification; area of assessment criteria in relation to water management as well as number of assessment criteria on water management at the vineyard/winery. The latter parameter was used in order to get an indication of "breadth" of the respective sustainability programs in terms of water management. The reasoning behind this indicator is an assumption that the more criteria there are, the greater likelihood of more requirements and better water management there is. Under this RQ, attention was also paid to the amount of levels, or categories, of the respective sustainability programs used in relation to assessment of member performance. However it should be noted that this says nothing about the actual content, or the difficulty in reaching a certain level.

Answers on *RQIb*, relating to program efforts to support members with implementation of sustainable water practices, were primarily obtained through interviews with the program representatives, and in some instances, complementing information was sought on the program websites and among internal documents. Information under particular focus was presence (and frequency, if applicable) of support in terms of educational material and guidance, such as in-person workshops, seminars or supportive documents in relation to the program Workbook, such as practical guides or manuals.

In terms of reported member performance on water management and inter-program variations, *RQ II* was addressed by seeking data on any available indication of member performance in terms of water use. The intended and ideal type of data that was sought was member averages (and range) on amount of water consumed per L wine or per bottle, and the method used for estimating this number. This type of data was expected to give an indication on how well the participants of the respective sustainability programs are managing their water resources, which would in turn allow for comparison and consequently for drawing conclusions on explaining factors based on findings form the other *RQs*. To approach an explanation of what explains reported differences; patterns in acquired data, input from interviewees, as well as support from previous research was used for this purpose.

However, as quantitative data on these metrics were lacking, performance indicators such as fraction and distribution of members in the respective performance categories within the

programs were used for analysis to a wider extent. This data was discussed and analyzed in relation to the other programs' means of reporting performance and their indicated performance, as well as in relation to previous findings in literature.

The last research question (*RQIII),* on (by program managers/representatives) perceived barriers and drivers for improved adoption of sustainable water management, was chiefly informed by answers from the program representatives. However many academic articles were also consulted in order to investigate how well the obtained answers aligned with previous findings on barriers and drivers for better uptake of water saving practices among wine producers.

The overarching research question was as stated above mainly informed through the answers of the previous research questions, but also by investigating how and through what forum the program representatives preferred to communicate best practice and share information relating to water management through the interviews.

3.3.1 Validation

For reasons of enhancing the legitimacy of the research methodology, transparency and repeated means of validation throughout the whole study were strived for.

For natural reasons, the choice of program representatives that provided information (through different media) for the respective programs will have large impact on the outcomes of this study. Thus, their ability to give an informed and objective representation of the actual situation in the respective cases was considered critical. To maximize the likelihood of talking to the right person, the initial email sent out requesting an interview was very descriptive, detailing what sort of information was sought for purposes of this research and what type of knowledge or access to information was desired in the posited interviewee.

Where possible, validation through triangulation was achieved through use of multiple data sources on topics addressed in the RQs and the interviews. All research questions were addressed using both primary and secondary sources, including online interviews and email contact with key persons of the respective case study objects, as well as academic articles and grey literature (such as internal documents from the respective programs and other industry branch organizations). Validation of information received from interviews accounted for a greater challenge, but was in available cases compared to findings in academia, particularly for *RQII* and *RQIII*.

It should be pointed out that the exploratory and largely descriptive nature of this study limits the degree of external validation, especially since no, or limited data on many of the questions addressed in this research have been obtained before, thus limiting opportunities for comparison.

In accordance with recommendations by Creswell (2014), further validation was obtained through 'member checking' before publication of the report, in other words confirming with participants part of the study that they agree on the reported content and interpretation of the provided information obtained through the interviews and emails, allowing them to comment on findings.

Moreover, peer debriefing was performed, primarily on the choice of research method, research questions, structure of the report and the content of the interview guide. The supervisor acted as the main peer, whom the research method and scope were discussed with several times over and revised accordingly. The interview guide was partly informed through

the help of one of the interviewees (Respondent 3), whom with the author has cooperated with before, and was considered having necessary insights into what questions are relevant to ask in order to enhance the study.

Lastly, validity was added through highlighting risk of bias of the interviewees, other sources of information, and by the researcher herself, as well as bringing light to flaws of the research method or collected data.

4 Findings: Case studies

In the following chapter, the results obtained from the literature study as well as from the interviews with program representatives from the selected case study objects, are presented. Information gathered in relation to the three research questions, as well sub-questions are addressed in separate sections, while the overarching research question '*How can vitivinicultural sustainability programs improve adoption of sustainable management of water resources among its members?*', rather is embedded in the 'Discussion' chapter, and discussed in relation to the findings presented below. *RQIa* and *RQIb* are addressed in separate sections, for reasons of natural division in topic, and for facilitation of interpretation and comparison of data in the following chapter. The findings are further separated into the individual case study objects, and primarily rely on data obtained through the interviews.

Table 4-1: Summary of findings on program design and assessment.

Program overview	**Country**	Australia	Chile	Portugal	South Africa	USA
	Organization	McLaren Vale Grape Wine and Tourism Association (MVGWTA)	Vinos de Chile (VDC)	Alentejo Regional Vitivinicultural Commission (CVRA)	Sustainable Wine South Africa (SWSA)	California Sustainable Winegrowing Alliance (CSWA)
	Framework	Sustainable Australia Winegrowing (SAW)	National Sustainability Code (NSC)	Wines of Alentejo Sustainability Program (WASP)	Integrated Production of Wine (IPW)	Sustainable Winegrowing Program (SWP)
Assessment design	**Workbook**	Yes	Yes	Yes	Yes	Yes
	Self-assessment system	Yes	Yes	Yes	Yes	Yes
	Performance differentiation	Five levels	None	Four levels	Three levels	Four levels
	Requirement on continuous improvement	Yes	Yes	No	No	Yes
	Third party validation	Yes	Yes	Yes	Yes	Yes
	Validation frequency	Every three years (certification), Annually (self-assessment)	Biannually	Annually	Every three years	Every three years (on site), annually (off site)
	Third party certification	Yes	Yes	In 2020	Yes	Yes
	Min. requirements for certification	Achieving a total score in the Workbook	100% of critical criteria, 60% of total score	-	65% of total score (100% of grapes)	Min. category 2, Self-assessment; critical criteria; identify priority areas; action plans
	No. water assessment criteria - vineyard	15	10	4	7*	11
	No. water assessment criteria - winery	-	10	15	5*	16

* Number of criteria in the Guidenlines' evaluation form

4.1 Program design and assessment methods

In this and the following section (4.2), the respective case study objects are presented individually in relation to *RQI*, i.e. how vitivinicultural sustainability programs are currently working for improved adoption of sustainable water management. While section 4.1 addresses this question with a focus on *RQIa*, i.e. on what areas or activities members are assessed on performance in terms of water management, and how; section 4.2 focuses on *RQIb*. More specifically, this section includes information on program design in relation to assessment method; type and amount of assessment criteria on water management; as well as on type and frequency of third party validation and certification of the different programs. Information on what sources program material and best practice are derived from was also sought, and is (in applicable cases) presented in this section. Unless otherwise stated, the provided information is obtained from the program representatives contacted in connection to this research.

4.1.1 SAW, Australia

The first phase for a member enrolled to the Sustainable Australia Winegrowing (SAW) program involves collecting data for completion of their self-assessment Workbook, which acts as the centerpiece of this program. In this Workbook, members conduct a self-assessment for each of its criteria, and are assigned a category ranging from 0-4, (or 'not applicable') based on defined requirements for each of the criteria. While a 4 represents 'Excellent' performance, a 0 indicates 'Needs urgent attention' (SAW, 2017a). The total score obtained in the self-assessment lays ground for certification under the program, in where members are placed in one of four color-coded categories: red, yellow, green and blue. The red category stands for 'needs attention' (0%-25% of total score), yellow represents 'good' (25%-50% of total score), green represents 'very good' (50%-75% of total score), and blue represent 'excellent' (75%-100% of total score) and is considered best practice, thus, it is the highest score one can achieve. The self-assessment takes place in an online platform, in where members can compare their results to their regional peers, national averages and vineyards of similar size or conditions (AWRI, 2018). In terms of water management, members are assessed on fifteen criteria, which are divided into three sub-topics that together form the Water Management chapter.[1] These sub-topics are: Water Source & Quality; Irrigation Management; and Irrigation System & Maintenance, with a weighting of 21.4%, 50% and 28.6%, respectively. The chapter on Water Management accounts for 13.7% of the whole Workbook, which consists seven chapters in total. (SAW, 2017a). Under each of these Water Management sub-topics, members are assessed on a total of 15 areas, which are presented in Table 4-2 below (Workbook material provided by Respondent 1)

Table 4-2: SAW assessment criteria from the Water management chapter.

Water Source & Quality	**Irrigation Management**	**Irrigation System & Maintenance**
Water source	Water Management Strategy	Irrigation system
Water security	Irrigation scheduling	Irrigation design
Water quality	Heatwaves	Irrigation system maintenance
	Water infiltration	Irrigation checks

[1] As previously mentioned, the SAW program is different to the other case study objects with respect to coverage, as this program so far is limited to only cover vineyards. This is naturally reflected in the assessment criteria for water management.

	Irrigation deep drainage	Pump maintenance
	Soil moisture monitoring and plant water monitoring	
	Irrigation records	

A member of SAW does not necessarily have to apply for certification immediately, but may participate in the SAW program only by completing a self-assessment in the Workbook and providing the requested data. However, members must have the intention to obtain certification in accordance with the certification rules set out by SAW. In order to become certified in any given category, a member has to obtain a score in each chapter of the workbook, which is not less than one category below the category certified in (apart from achieving a total score in the score range for that category). (SAW, 2017b). The first step for members on the road to becoming certified under the SAW program involves defining the so-called "Unit of Membership" that the member wants certified. Simply, this is a term for which and how many vineyards - using similar management practices and farming systems on each site, as well as similar input usages and operations – that will be self-assessed in each year through the Workbook, that the certification will apply for. A Unit of Membership is certified after an accredited third party has verified the data provided by the member in the self-assessment. Once certified, SAW members are automatically also eligible to use their certification towards membership in Entwine. However, in order to become certified under the Entwine program, a member needs to score at least 3 for all chapters of the Workbook. Each certified member must be prepared to have the self-assessment of their Unit of Membership audited in any year, as members selected for audit are randomly selected by the Board each year, however, accredited third party audits are in general conducted every three years. It is a requirement under the SAW rules that members must be able to demonstrate continuous improvement in all operations. Indicators assessed to prove this include the self-assessment Workbook, audit results from an independent accredited third party certifier as well as action plans in where areas of improvement are emphasized. (SAW, 2017b).

As briefly mentioned in the literature review, members of SAW and other programs under Entwine Australia report on industry metrics as set out by Entwine. This allows members to compare their performance against other members, and find regional, state, zonal or national benchmarks for different performance areas - including water use. Vineyards also have the possibility to compare their performance to other members in the same climatic zone (AWRI, 2018).

The program material has been largely influenced by input from regional wine growers and producers, industry organizations (especially MVGWTA), by research in the field and by the Californian programs Lodi Growers and CSWA's SWP (SAW, 2017a; Santiago-Brown et al., 2014a). During a program review conducted last year, a number of best practice and legislative documents relating to winegrape growing were consulted to ensure that the program content was up-to-date, and all the chapters of the Workbook were discussed with the authors of each chapter, and peer reviewed by individuals from industry bodies, universities, regional wine associations and wine industry consultants. This very thorough review resulted in further improvements to several parts of the Workbook (SAW, 2017a; Respondent 1).

4.1.2 NSC, Chile

In Chile, the assessment system of the National Sustainability Code (NSC) consists of a general Compliance Standard and a point-based, Checklist system in the three different areas described in the Background section: Green (vineyard), Red (winery) and Orange (social). The

Checklist consists of both 'critical requirements' which members have to comply with, as well as non-critical, or general, requirements. The criteria, procedures and requirements for the NSC are stipulated in a 'General Regulations' document, also being part of the Code.

In the green area, i.e. the vineyard, members are assessed on four distinct sections: Pre-planting vineyard management; Management of established vineyards; Environment and biodiversity; as well as Implementation and follow-up. The maximum score one can achieve in the Checklist's green area is 704 points, of which assessment criteria relating to water use make up 40 points or 5.7% of the total score. If only considering the section concerned with management of established vineyards, assessment criteria for water instead make up 6.9% of the total score. In the red area, i.e. the one relating to activities in the wineries, bottling plants and other facilities relating to wine production, assessment criteria relating to water management make up a larger fraction of the maximum score (378 points), more precisely 20.6%. Lastly, in the orange area - which is concerned with social issues – assessment criteria on use of water resources (lumped together with energy) make up 4.2% of the maximum score of 592 points (Converted from the National Sustainability Code). Although an important foundation of the certification process, the Checklist assessment points only serve as reference to those implementing and evaluating the NSC (who are able to comply with the requirements of the Standard), and do not represent the full formal requirements of the certification process (Vinos de Chile, 2012).

As mentioned in the literature review, instead of certifying a final product (i.e. bottle of wine), or individual vineyards, NSC certifies the *management* of the company, which is a bit different compared to other sustainability initiatives. In other words, NSC certifies the sustainability performance of a company's management as a whole, and is applicable to all types of wine companies, no matter their scale of production scale or operational condition. The certified management might for instance apply to wine companies, vineyards, grape producers or facilities related to wine production, such as wineries and bottling plants (Vinos de Chile, 2012).

There are two levels of the NSC. Level one is intended for newly enrolled members who have joined the Code and are working on its implementation, while level two is the level of certification, which is accessed once members have approved an accredited third party audit (Vinos de Chile, n.d.). Once certified, the management of the company is entitled to carry the logo "Certified Sustainable Wine of Chile" (Vinos de Chile, n.d.). Vinos de Chile works with five different internationally accredited third party certification bodies, which currently conduct member audits on a biannual basis (although this interval aims to be shortened) (Respondent 2). The companies to be certified may choose for themselves by which certifying body they wish to work with. It is compulsory under the NSC for members to conduct internal audits annually, which is also checked during the external audits. The certification process is open for everyone, not only members of Vinos de Chile. (Respondent 2).

The documents necessary to fulfill the requirements of the Code are after a governmental decision not made public, but are only accessible to members enrolled to the NSC (Respondent 2), thus insight to specific assessment criteria is limited. There is no online self-assessment platform, but once enrolled, members get access to all the necessary documents for membership and certification such as the Compliance Standard, the Checklists for control points and for audits, self-evaluation forms, as well as contracts relating to e.g. use of the logo (Vinos de Chile, 2012). However, the Checklist for the NSC is available online, from which an indication of assessment areas are given. Table 4-3 is an adaption of this checklist, divided into assessments applicable to the vineyard (green area) and winery (red area).

*Table 4-3: Assessment criteria as adapted from the NSC Checklist. *: Found under red area, but relates to green area operations.*

Vineyard (green area)	Winery (red area)
Presence of water conservation program	Disposal and consumption of water
Maintenance of irrigation system to avoid leaks	Annual evaluation of water quality
Irrigation water quality	Presence of system to measure water input/output to winery
Uniformity of water application through the irrigation system	Presence of water consumption indexes with respect to wine production
Regular maintenance of irrigation system and equipment	Measures for avoiding contamination of water sources
System for measuring water flow	Use of dry cleaning systems or other measures to reduce water use
Consideration to soil, plant, and atmosphere conditions when calculating irrigation needs for more efficient water applications	Staff training on benefits of efficient water use (at winery and at home)
Use of recycled water for irrigation*	Promotion of water saving in protocols, winery procedures, systems and equipment
Promotion of plants with low water consumption*	Presence of water reuse systems
Irrigation timing in order to avoid evaporation losses*	Usage of water saving signs

The Code is designed so that farmers, no matter their financial situation, will be able to be assessed on sustainable management of water (and other resources). The most water efficient irrigation techniques are often expensive, and some farmers are financially restricted to access this type of equipment. The NSC therefore rather assesses members based on their individual capacity, avoiding requirements on advanced equipment and other actions involving substantial expenses. In terms of water management, this for instance means a requirement on measuring the company's use of water and to reduce it, rather than achieving a fixed amount of water consumption per unit grapes or wine. The interviewed General Manager at Vinos de Chile (2018) stressed the importance of considering not only the varying personal conditions of the members when designing a sustainability program, but also the environmental setting. Chile is a very stretched country, with great variance in climatic conditions, thus it is neither fair nor feasible to have the same requirements e.g. in terms of amount of irrigation for all members across the country. According to the General Manager, the creators of the NSC wished to have an inclusive sustainability program and implement a system where there is no differentiation between poor or well performing members, but rather to have a high threshold and make sure that all members are working towards sustainable operations based on their own capabilities. A goal behind the program is to be able to claim that *Chile* is a sustainable wine producing country, rather than highlighting individual producers or wineries (Respondent 2).

To become certified is a demanding process, as members have to comply all the critical criteria and achieve at least 60% of total score in the first certification cycle. Moreover, the NSC has an internal requirement on continuous improvement among members. In other words, for each certification cycle members need to improve the total score from the Checklist.

Members are primarily assessed qualitatively in terms of water management. However, the Code is revised every second year, and in the new version of the Code (currently being developed), more quantitative performance indicators will be used (Respondent 2).

The material of Chile's National Sustainability Code (NSC) is partly based on research from experts at Talca University (International Trade Centre, 2011), as well as from different research areas under the Vinos de Chile consortium. One of the research groups is solely focused on water management, from where research outcome help informing the content of the NSC (Respondent 2). The content of the NSC, including the Standards, Checklist and certification criteria, is revised on a biannual basis by the Standards Committee through coordination by the technical unit of Vinos de Chile. The Standards Committee consist of members from various wine industry organizations around Chile, where all input is weighted equally (Vinos de Chile, 2018). On request of wine companies or by members of the Norms Committee or the Code's Superior Committee, exceptions in terms of one-off changes to the Code may occur, given that proposals are technically grounded (Vinos de Chile, 2012). In order to assure continuous work towards sustainable management and operations, it is compulsory for members to conduct internal audits annually, while third party audits only need to be conducted biannually (Respondent 2). No more specific details on what sources the NSC material relating to water management stem from, i.e. assessment criteria or best practices, could be obtained from neither primary nor secondary sources.

4.1.3 WASP, Portugal

The Wines of Alentejo Sustainability Program (WASP) is a voluntary sustainability program, and open for all growers and vintners to take part in. Members of WASP annually assess their sustainability performance through the use of a web-based self-assessment tool containing all assessment criteria and chapters from the underpinning Workbook of WASP. The Workbook has 11 'Primary intervention chapters' and 108 criteria, and another 5 chapters and 70 criteria, which are accessed once members have completed these primary chapters (Vinhos do Alentejo, 2018a; Respondent 3). In the self-assessment platform producers indicate their performance on a scale of 1 – 4[1] (4 being 'Developed', i.e. most sustainable, and 1 being 'Pre-initial', i.e. worst performing) against a set of criteria (e.g. for water use efficiency/energy efficiency measures). Upon completion of the self-assessment, members are assigned a 'General Sustainability Category' (divided into the four levels mentioned above) (Vinhos do Alentejo, 2018a). The results of the self-assessment are later validated either with the submission of photographic 'evidence' by members or with a site visit by WASP staff. Based on the self-evaluation, members are encouraged to develop and implement action plans in order to improve their sustainability performance where there is need for improvement, or non-compliance occurs (Respondent 3). WASP staff validates that members follow up on these action plans, and once achieved, the assessment cycle repeats itself.

Only members that reaches the General Sustainability Category of 'Developed' after completing all 16 chapters will be able to proceed to a third party validation and certification process and get formal recognition of sustainability for their production process (Vinhos do Alentejo, 2018a). However, being created in 2015, the program is yet at its infant stages and assessment criteria need to be made auditable before 3rd party certification is possible. According to interviewed staff managing WASP, a 3rd party certification scheme will be in place between 2019 and 2020 (Respondent 3).

[1] In case the assessment criteria do not apply for the member, a value of 0 is chosen.

Of the total 16 chapters of the Workbook, two main chapters deals with water management – one applicable to the vineyards and one for the wineries. Members are assessed in four different areas relating to vineyard water management, and eleven areas relating to water management in the wineries, which are presented in Table 4-4 below.

Table 4-4: WASP assessment criteria from the Vineyard and Winery chapters on water management.

Vineyard	**Winery**
Irrigation strategy	Planning, monitoring, objectives and results of water conservation
Monitoring and correction of irrigation water quality	Planning, monitoring, objectives and results of the quality and origin of water
Irrigation system and its functioning	Water supply
Management and control of water volume applied & irrigation needs	Liquid effluent for decantation basins or municipal wastewater treatment systems
	Process liquid effluent - Effluent base discharges
	Septic hosts or water treatment stations
	Rain water
	Grape recovery operations
	Pressing operations
	Tanks and pipes
	Cellars
	Cleaning of filters
	Bottling
	Laboratory
	Landscaping

The methods used for assessing member performance in terms of water management are mainly of qualitative nature, but the way of reporting can varies among members. For instance, if required to install a flow meter measuring water use, some members provide quantitative records on their water use and the development over time, while others only provide evidence of the installment of the flow meters. However, the program is intending to move towards a greater use of quantitative data in the future in order to better track development of program members (Respondent 3).

The development of program contents in terms of educational and assessment material has been formulated in collaboration with national and international universities. As such, the metrics and recommended practices used in the assessment criteria are grounded in research and are also in line with the guidelines from the OIV (Respondent 3). The CVRA and Managers of the WASP program also work closely with industry branch organizations, research organizations and governmental bodies such as the EPA (Respondent 3). According to Respondent 3, the program takes much inspiration from the sustainability program developed by CSWA (SWP), which is reflected in the program design, content, and assessment criteria of WASP. The partial adoption of CSWA's program design and content was driven by the Californian wine industry's experience in the field of sustainability and its perceived success in terms of scope and adoption of sustainability practices among members. And, as the respondent pointed out during the interview: *"…there was no point in reinventing the wheel [when developing the program]"*. Although a lot of inspiration has been taken from CSWA, program content has also been influenced by the work of sustainability programs in Australia and Chile.

4.1.4 IPW, South Africa

The IPW scheme is, as earlier mentioned, divided into two central documents – the guidelines and the manuals, which are divided into cellar (winery) and farm (vineyard). The guidelines, which are updated biannually, consist of recommendations and minimum standards of what should be done, while the manuals are more of practical documents showing how the guidelines should be implemented for further third party auditing and WSB certification (Santiago-Brown, 2014a). The guidelines include critical aspects of good practice relating to grape and wine production, as well as minimum requirements for compliance with relevant South African legislation (e.g. environmental issues, labeling and food safety) (Santiago-Brown 2014a; IPW, 2015; IPW 2016). The guidelines are also designed to be compliant with FIVS and OIV guidelines and principles on environmental sustainability within the wine industry (IPW, n.d.). As part of the guidelines document there are self-evaluation forms for both wineries and vineyards that acts as evidence for compliance to the guidelines, which needs to be completed annually. In these forms members can either score 'Good' (5 points), 'Average (2-3 points) or 'Poor' (0 points) for the respective assessment criteria. The manuals indicate what the different scores for each of the assessment criteria in the guidelines corresponds to in practice. In order to become IPW accredited, wine producers must score a minimum of 65% of the total score of the guidelines and 100% of the grapes must comply to IPW requirements, including all steps in the production chain, from cellar to bottling plant (WOSA, n.d.a).

In contrast to the other sustainability programs investigated, the assessment criteria in the IPW guidelines are not clearly separated into a section or chapter covering water management, but is rather embedded in the guidelines and are of more general nature. This makes it difficult to specify the amount of criteria related to water management that members are assessed on. Moreover, in the guidelines for farms there are two separate tables: Table 1A: Environment management of farming activities and 1B: Conservation and management of natural areas (to be filled out by members). These tables act as an evaluation form and are directly related to the content of the guidelines, however, they do not appear to be exhaustive in terms of guidelines coverage, which further complicates counting of assessment criteria. However, in the guidelines for farms there are three out of fifteen guidelines that are more or less directly related to water management. These are 'Conservation and improvement of the farm and vineyard environment', 'Irrigation' and 'Cultivation practices'. The individual guidelines can be compared to the 'chapters' in the workbooks of the other sustainability programs. If looking to the tables mentioned above, seven assessment points relate to water management. (IPW, 2016).

For cellars, only two out of fourteen guidelines are directly related to water management. These are 'Zoning, registration and analysis of incoming water' and 'Wastewater management'. However, water issues are also partly addressed in 'Implementing and maintaining infrastructure and equipment' and 'Management of solid waste'. In terms of assessment criteria in the evaluation form, five of these are considered directly related to water management (IPW, 2015). The guidelines declare that due to differences in soil type, canopy and climate, water requirements for all vineyards are not the same, but vineyards should instead be irrigated according to their individual needs. In line with the South African 'National Water Act No. 36 of 1998' and the 'Conservation of Agricultural Resources Act, No. 43 of 1983', the guidelines requires vineyards to:

- Have proper irrigation scheduling that is in accordance with water retention ability of the soil, the physiological stage of the vineyard, the crop factor and climatic conditions.
- Have an irrigation system designed to ensure effective water distribution in the particular soil type without wetting bunches regularly.

- At all times correctly use and maintain the irrigation system
- Only use fertilizers through the irrigation system if the system has been designed accordingly and the nutrients applied do not exceed the recommended rates for soil application.
- Keep records of all measurements/determinations regarding each vineyards' water requirements, as well as of all applications of water should be kept to prove that sufficient water was given to satisfy requirements, but no more (IPW, 2016).

To ensure water use efficiency at the wineries, cellar managers are expected to effectively manage winery water use and its potential financial and environmental impact; to make provision for improvements on water use; and to be knowledgeable on how wastewater is generated and what management options are available in order to minimize the impacts of these streams, as well as on how to meet legislative requirements (Respondent 4).

In terms of wastewater management for wineries, the guidelines require producers to keep weekly records of wastewater quantity; monthly records on wastewater quality (analyzed by accredited laboratories) and regular records before disposal or irrigation. They further require producers to adopt best practices for storing and disposing wastewater (the latter based on a formal agreement with a local authority or the General Authorization for Water Affairs) (IPW, 2015; Respondent 4)

The latest audit policy to be found on IPW's website is from 2008, and in this document three different categories for member audits can be found: farms; cellars; and bottling facilities. For all categories there is a demand on completing the self-assessment form, which, once finished, must be uploaded to the online platform for members. The requirements for bottling plants and cellars follow the same steps, where upon completion of the self-evaluation form (for the respective operations), staff from the IPW office verifies that forms have been fully and accurately completed. When this is done, accredited auditors of the Wines and Spirits Board (WSB) make an external audit, either as part of an annual sample or at own request. Registered professional soil and environmental scientists as well as professional winemakers are responsible for compliance monitoring on water management requirements, also them appointed by the Wine and Spirit Board as third-party auditors (Respondent 4). The assessment for farms are similar, although before an external audit by WSB takes place; the cellar where the grapes are delivered has to verify that the self-evaluation forms are accurately completed, rather than IPW staff (IPW, 2008). Once certified, producers are further independently audited on a spot check basis in order to confirm compliance. Each year one third of the wine producers are inspected, (i.e. in a three-year cycle all members are inspected) (Santiago-Brown et al., 2014a).

According to Santiago-Brown et al. (2014a), the consultative audits under the IPW program are "*one of the most complex and strict auditing processes of its kind"* (p. 2042), as apart from assessing producers on fulfillment of necessary requirements for certification, the auditors also help producers meeting program requirements by individually consulting them in how to reach the pass mark, by sharing scientific knowledge, informing members about minimum requirements of South African law in relation to the program assessment, and suggesting training when deemed needed (Santiago-Brown et al., 2014a).

The content of the IPW program in South Africa is underpinned by research and has a strong technical basis. The guidelines are revised and refined by the Wine and Spirit Board (WSB) biannually, unless changes in relevant environmental legislation or standards necessitate immediate amendments. This process is coordinated by the organizations ARC Infruitec-Nietvoorbij and Enviroscientific and overseen by the IPW committee, which consists of

industry experts; including viticulturists, wine makers, researchers, technical experts, as well as representatives from the agrochemical industry (Respondent 4). The IPW program is designed to comply with international guidelines and principles on environmental sustainability within the wine industry from both FIVS and the OIV (IPW, n.d). According to information found on the website of Wines of South Africa, which is a body that represents all South African wine producers with product exports, the guidelines are planned to cover water conservation to a larger degree in the future, due to the pervading water scarcity in South Africa (WOSA, n.d.a).

4.1.5 SWP, USA (CA)

The central tool produced by CSWA, acting as the basis for the Sustainable Winegrowing Program (SWP), is the Code of Sustainable Winegrowing, known as 'the Workbook'. The Workbook is a voluntary self-assessment tool free of access to anyone, which allows users of the tool to place themselves in one of four categories for each criterion assessed. Each assessment criterion defines the actions necessary for reaching the different categories, where category 1 represents the lowest, and category 4 the highest degree of sustainability performance. Further explanations of how to practically adopt the different criteria and their categories are given in the Workbook appendices. Category 1 is designed to at least meet legal requirements for the specific criterion, while the other categories is intended to move vintners and growers beyond compliance and approach increased sustainability through stricter requirements (California Sustainable Winegrowing Alliance et al., 2012). It is important to note that all criteria are not scaled the same, i.e. the categories 1-4 between criteria (or across chapters), do not necessarily represent the same level of sustainability. To clarify, it may be a lot more demanding to achieve a category '3' or '4' for some criteria than others (CSWA, 2015). The Workbook was first published in 2002 and has since then issued two new editions. The latest version was published in 2012, which is the version refereed to in this section.

The Workbook has two (out of fourteen) assessment chapters solely dedicated to water management – one for vineyards ('Vineyard water management') and one for wineries ('Winery water conservation and water quality'). The chapter relating to vineyard water management covers eleven criteria on which members are assessed, whereas the winery water management chapter has sixteen criteria, which are presented in Table 4-5 below.

Table 4-5: Assessment criteria in the vineyard and winery chapter on water management found in the SWP's Code of Sustainable Winegrowing (California Sustainable Winegrowing Alliance et al., 2012).

Vineyard	Winery
Water Management Strategy	Water Conservation Planning, Monitoring, Goals, and Results
Monitoring and Amending Quality of Irrigation Water	Source Water Quality Planning, Monitoring, Goals, and Results
Off-Site Water Movement	Water Supply
Irrigation System	Water to Process Water Ponds or Public-Owned Treatment Works
Distribution Uniformity for Irrigation Systems	Process Water Discharge - Water from Process Water Ponds
Filters and Lines	Septic Systems or Onsite Systems
Water Budget	Storm Water
Measuring Water Use	Crush Operations
Soil Water-Infiltration Rates and Water-Holding Capacity	Presses
Soil Moisture and Plant Water Status Monitoring Methods	Tanks and Transfer Lines
Planned Deficit Irrigation through Regulated Deficit Irrigation	Cellars
	Barrel Washing

	Barrel Soaking
	Bottling
	Labs
	Landscaping

Once members have completed the self-evaluation form, they have the option (since 2010) to obtain the third-party certification - Certified California Sustainable Winegrowing (CCSW), given they meet its requirements, including achieving at least a Category 2 in all the criteria being assessed, demonstrate continuous improvement, identify priority areas and provide action plans for corrective actions where needed. Only since last year the wines passing the CCSW audit are allowed to carry a CCSW-logo on their bottles prove their sustainability performance. To become CCSW certified, members are required to: conduct annual self-assessments using the Workbook; to meet all 'prerequisite criteria' of the Workbook (about one third of all criteria); to identify priority areas and creating action plans that are implemented and updated annually, as well as to demonstrate continuous improvement (California Sustainable Winegrowing Alliance et al., 2012).

The assessment criteria of the Workbook are typically of qualitative nature, and no requirements on amount of water use per unit of wine or grapes produced are given. Producers must however keep track of certain metrics such as total winery water use (criteria 10-1) in order to be placed in a category, indicating that quantitative data on water use exist.

Broadly speaking, the highest achievable category of each of the Workbook criteria reflects current knowledge on best practices, and this knowledge primarily stems from academic research, from topic specialists in different areas of sustainability, on regulatory frameworks and from knowledge of the Joint Committee of the program (which is comprised of more than 50 growers and vintners from different parts of California and represents varying size operations). More specifically, the vineyard chapter on water management is largely based on the content of the Lodi Winegrower's Workbook (which was among the first books of its kind in the wine industry, and is in turn based on research from University of California, industry experts and vineyard experience). The chapter on water management in wineries was developed by sustainability experts, with input from a diverse group of vintners who participated on the Sustainable Winegrowing Joint committee (and is also largely based on research and winery experience). The program content is continuously evolving and updated as needed by seeking input from growers (e.g. CSWA, 2009), experts, consultants, academics, engineers, and regulators. Their Board of Directors are largely involved in the development of the educational material, while the Joint Committee helps outlining key best practices for members. (Respondent 5).

4.2 Member support for improved water management

In this section, an overview of what the investigated sustainability programs are doing in order to facilitate for improved water management through different means of support for its program members is given. Individual efforts of the different programs are presented below, and again; unless otherwise stated, reported information is given by the respective program representative.

4.2.1 SAW, Australia

The SAW program arranges and designs educational events based on identified knowledge gaps and needs from the results of the reported self-evaluations of the Workbook. They also run so-called 'Viticulture reference groups', which is made up of a committee of local growers

and contractors. This committee has strong relationships with growers in the region and understands their individual needs of support for implementing sustainability practices in the field, and helps them meeting these needs through different workshops and forums are designed accordingly. SAW also regularly organizes guest speakers to take part in or present workshops. The aim of these workshops is to create a space where growers can come together to talk about key issues they are facing and potential solutions, with a focus on sustainable winegrowing. One example of workshop series that are repeatedly used in the program is the 'Focus vineyard series', which is a project with the purpose of identifying "focus" vineyards in the region to be used for knowledge sharing. The chosen vineyards have different management practices (e.g. organic, conventional or biodynamic) and are across different sub-areas, but grow the same grape variety. In these workshops, some of the commonly addressed topics are 'Optimising water usage while improving grape and wine quality' and 'Irrigation management'. These generally well-visited workshops are open to all members and have so far been very well received.

MVGWTA also run projects to study and/or demonstrate water security issues in the region under the SAW program. One such project is the 'Telemetry Project', which in collaboration with governmental bodies and industry actors arranges a pilot study to help understand and monitor the regions' water resources. The aim of the study is to combine knowledge to progress the McLaren Vale regions future water resources, providing continuous improvement through improved water transfer, licensing procedures and establish automatic monitoring of bores.

Moreover, the MVGWTA has a vineyard that is used to carry out trials and demonstrations for educational purposes. Recently winter watering has been conducted to demonstrate how soil can be used as a dam for combating potential production losses in dry times.

As the online member-portal could not be accessed, there is no insight into member support in terms of practical documents and guides for the implementation of program requirements with respect to water management.

4.2.2 NSC, Chile

In Chile, several educational events are held each year in where they arrange speakers, workshops and the like in order to improve sustainability performance among members. Specific details on what these events hold in terms of water management was not given. Other means of member support includes governmental subsidies (in exceptional cases) for small producers who lack financial resources, in order to help them to implement the requirements of the NSC (Respondent 2).

4.2.3 WASP, Portugal

Under the WASP program, the Sustainability Manager of the program holds workshops and trainings for members 2-3 times a year, of which some are focused on water management. All members, and especially the top management from the represented wineries and vineyards, are invited to participate in thorough presentations on best practices in terms of water conservation and management, both in the vineyard and winery. In relation to this, it should be pointed out that the CVRA so far only have one employee working full-time on the WASP program, which naturally put constraints to the extent of support that members can receive.

Apart from the workshops, members hold access to a range of supportive documents in the online portal 'SIVA', in where the Workbook for self-assessment is accessed, e.g. a practical manual for cleaner production in wineries (by Engel et al., 2015). Still, the categories for each criterion in the Workbook are formulated so that it should be rather self-explaining for

members what they need to do and how in order to reach a higher category, i.e. improve performance. Thus, further instructions and support for members are not necessarily deemed necessary, according to Respondent 3.

The WASP homepage has a page covering best practices in terms sustainability in different areas of production, which could also be used as support for members. Here, one page is dedicated to water use and quality, where some suggestions of improvements in the wineries, vineyards and bottling plants as well as regional benchmarks for the respective areas can be found (Vinhos do Alentejo, 2018b). However, this page appears to rather be program-explaining in terms of challenges and objectives around regional water use in connection to wine production, than providing support for members.

4.2.4 IPW, South Africa

Staff of the IPW program advise and support vintners and growers on sustainability through IPW training workshops and case studies, but do not have specifically assigned consultants working as employees of the Board for these purposes. However, the IPW does sometimes works with professional consultants for similar purposes, and they are partners with the World Wildlife Fund (WWF) and are involved in their water stewardship programs, from where there is plenty of information available to support producers in efficient water management. Authors of the central documents try to assist members by summarizing most of the important information in the manuals and guidelines, but apart from these central documents, no other official extra information or brochures on efficient water management in the vineyard, in the cellar or on farms exist. As South Africa is a large country with varying amounts of annual rainfall in the different production regions, best practices and methods of managing water efficiently are considered to differ among regions – thus, it does not make sense to have highly detailed instructions on best practices in terms of water management, as this might not apply for all regions, Respondent 4 reasons. Although no supporting material exist to inform members on best practice for the requirements under the IPW guidelines, some best practices are based on formal agreements with local authorities (e.g. the General Authorization for Water Affairs) such as for disposal of wastewater (Respondent 4).

4.2.5 SWP, USA (CA)

The CSWA arranges workshops as part of the SWP, which often are federal and state grant funded. Sometimes these workshops cover sustainability in a general sense, while other times they are much more detailed in character, focusing on one particular issue at time, including water management – a very central topic among growers in California. These workshops are referred to as "Targeted education work shops", in where the main focus is on best available practice of the different topics covered. CSWA also has plenty of practical online material, such as videos, guides and case studies, acting as support for their members (Respondent 5).

It is a strive of CSWA staff to always improve the program internally and do more outreach to its members, which is why they are currently underway changing to a new database in where it will become a lot easier to encourage members to improve in relevant areas and providing direct feedback and instructions in how to do so. For instance, pop-up windows will shows up as producers fill out the self-evaluation form, informing them what to do, while weighing costs and benefits from doing so. The software will also be able to tell its users where to access information on relevant issues after the self-assessment is done. Some of the language that will be used in the pop-up windows is exemplified below:

- *Congratulations on completing a vineyard or winery sustainability self-assessment. What's next? There are several ways to further your commitment to sustainability:*

- *Run one of the many reports [link to page] to see how your practices compare to your peers or get suggestions on action plans for continuous improvement by clicking on the Reports tab*
- *If you are interested in certification, review the Step-by-Step guide and other resources [here], run the Certification Audit Checklist Report, or submit an application*
- *Start calculating your metrics for water, energy, greenhouse gases, or nitrogen use by clicking on the metrics tab*
- *Download your Recognition of Self-Assessment Completion to communicate your commitment to sustainability*
- *Write Action Plans for improvement using a template available from the Home Page*
- *Attend an educational workshop or webinar*

In addition to a plethora of education material available on their website, including educational videos, case studies and useful links on water efficiency (CSWA, 2018), action icons are embedded throughout the online self-assessment portal to help encourage further action and continuous improvement. When members hover over the icons, text appears suggesting further examination of cost/benefits analysis of certain practices; exploration of an metrics calculator to begin tracking use of key resources; and using a reporting feature to evaluate practices in areas that have been identified as high impact practices (environmentally, economically, and socially). In Box 2 some information that came up during interviews on how the SWP and other programs are spreading information outside the program is given.

As it is a (challenging) requirement under the program for members to continuously improve their performance, and to provide action plans indicating how they will improve or advance to a higher level the following year, the CSWA further supports their members by providing action plan templates. Over the years the CSWA has tried out several different means of supporting their members in order to meet different needs and to seek preferred means of communication and support. For instance, they have shifted between having in-person workshops to offer online webinars (taking travel times, access and other constraints into account), and have offered the targeted educational events during different times of the day. It however remains unclear what method should be considered superior, as needs and ways of learning varies among members.

Box 2: Information sharing among sustainability programs

Information on new research, best practices and best available techniques are primarily shared and discussed with other sustainability programs through the international organization FIVS, in where water management receives a lot of attention, which acts as a great forum for managers in wine sustainability programs to communicate new research on best practices and new research relevant to sustainable wine production (Respondent 3 & 5). In terms of knowledge sharing, CSWA are members of FIVS and considers it a great platform for sharing information. Although limited in time, resources and staff power, Respondent 5 expressed that the CSWA try to participate as much as they can, as they desire a more open dialogue between different sustainability programs and other stakeholders. Staff of the CSWA share information by making new material publically available on their website (e.g. from research projects), and by sending information out to stakeholders and partners in the state and the US, and also tries to share their resources internationally, e.g. through FIVS. A perceived issue with FIVS however, is that it is a members-based organization that is costly to join. According to Respondent 5, the CSWA are only able to be part of FIVS is because their parent organization - the Wine Institute, is a FIVS member, meaning avoided membership fees for the CSWA. Respondent 3 and 4 reported that WASP, respectively IPW, also are members of FIVS and use it as a forum for information sharing.

4.3 Reported performance

This section covers answers in relation to *RQII*, i.e. whether performance differences between the investigated sustainability programs exist in terms of member water management. To address this, data on water use and management was sought among program representatives and online databases of the respective programs, and are presented below.

4.3.1 SAW, Australia

In terms of performance, the latest indication of SAW member results is provided in the report of the growing season's results from 2016-2017 (SAW, 2017a). Performance of individual SAW members is not provided, but scores are averaged across all members. Of all seven chapters of the Workbook - the chapter on Water Management is the chapter in where members score the highest on average (75.9%), (however, these water management scores are actually 1.8% worse compared to the previous growing season) (SAW, 2017a). Within the sub-topics, Irrigation System & Maintenance was the strongest one, with only a 21.6% gap to best practice, closely followed by Irrigation Management (22%). Members had a greater gap (32.3%) from best practice on the Water Source & Quality topics, as can be seen in Figure 4-1.

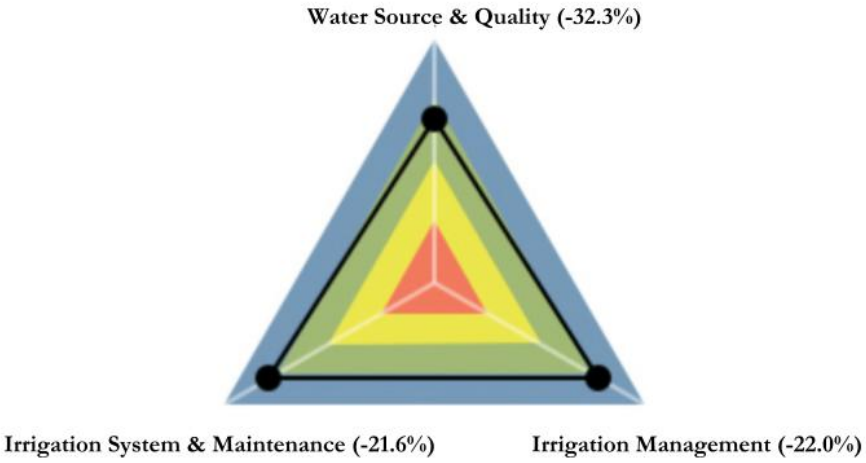

Figure 4-1: Reported overall performance of SAW members on the Workbook chapters on Water Management. Source: SAW, 2017a.

SAW members achieved a rather drastic reduction of applied irrigation water compared to the previous growing season, with a reported water use of 0.95ML of irrigation water/ha of vineyard compared to 1.43ML the previous year (SAW, 2017a). Although a quantitative estimate, no Water Footprint estimation was provided in where green, blue and grey WFs are taken into account. The provided estimate can closest be likened to a blue WF only. According to the same report of 2016-2017, 5% of SAW member-'s vineyards are dry grown. With respect to water sources, 60% of the vineyard irrigation used in McLaren Vale is from reclaimed water (i.e. wastewater that is captured, treated and reused, instead of discharged), while 35% is from ground water and 3.7% is from surface catchment water.

Theoretically, numbers on average water use for SAW members per unit of produced wine or harvested grapes should be possible to attain, as they are keeping quantitative records of water use (AWRI, 2018). However, no such information could be obtained from the SAW representative.

4.3.2 NSC, Chile

As the management of the NSC actively chooses to not compare the performance of individual members, no data in terms of quantitative nor qualitative member performance on water management could be obtained, even though they in theory could do so as they hold the data records (Respondent 2). Certain certified companies choose to include records on water management and other environmental issues in their sustainability reports, however, these are typically top performers and their results do not reflect the Chilean situation as a whole, thus these records are not considered relevant for the purpose of this research. Some members have proposed to have different levels of performance, but this has been disregarded, and if members wish to be differentiated as high performers, the operators of NSC refer them to other certification programs. The reasoning behind this is that everyone on the program should get the same degree of recognition, no matter the score achieved (Respondent 2).

4.3.3 WASP, Portugal

Raw data on the distribution of latest available member performance on water issues were provided in an Excel sheet by the Sustainability Manager of the program, and converted into graphs by the author. These graphs can be found in Appendix C. In terms of vineyard management, members performed best (largest fraction of members in the 'Developed' level) in the areas of Irrigation strategy (38.4%) and Irrigation system (38.7%) and functioning. In the wineries, the best performing areas of water management were: 'Septic host systems or water treatment'; 'Pressing operations'; and 'Grape recovery operations', with respectively 54%, 52 and 52% of members in the 'Developed' level. Areas having the greatest improvement potential (largest fraction of members in the 'Pre-initial level') were 'Monitoring and correction of irrigation water quality' (vineyard), and 'Planning, monitoring, objectives and results of water conservation' for the wineries.

Looking to performance over time, and in relation to other assessment chapters of the Workbook, both water management in the vineyard, as well as water conservation in the cellars have been improved over the last three years (Figure 4-2), however the former area more considerably so, which also has a higher average score (compare 3.25 to 2.5). In comparison to the other assessment chapters of the Workbook, these chapters appear to be average performing, where only cellar disease and pest management sticks out as a top performer.

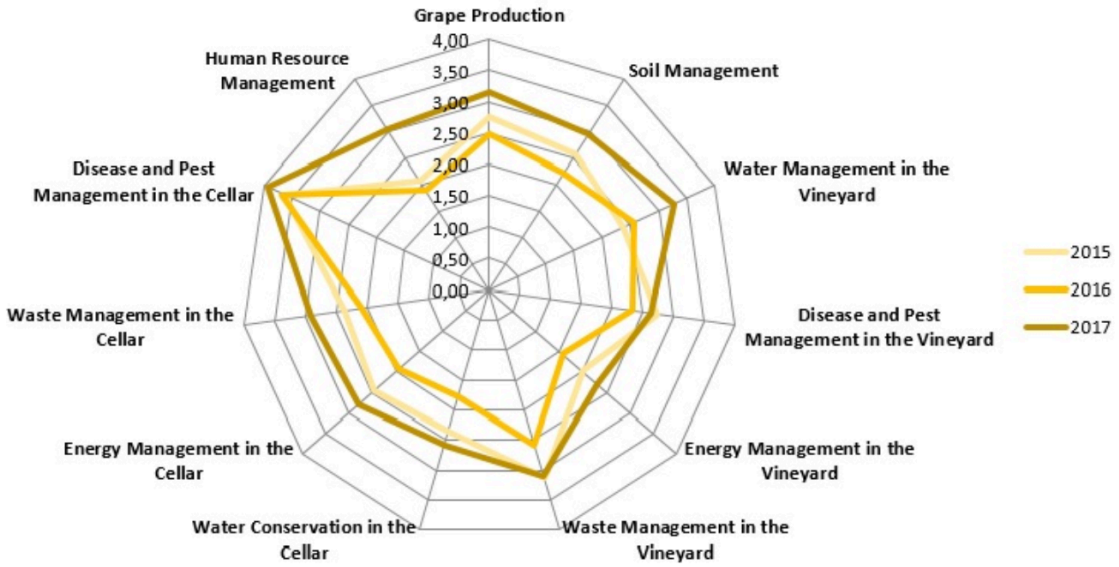

Figure 4-2: Reported overall performance of WASP members on the different Workbook chapters. Source: Vinhos do Alentejo, 2018a.

On the WASP website, a regional estimate of water use per produced liter of wine was reported to range between 1.2L - 14.4L, based on the report of Engel et al. (2015) (Respondent 3), however this estimate exclude water use at the vineyards (Vinhos do Alentejo, 2018b). The same webpage states that other wine producing countries have a reported best practice of water use between 0.75L - 1L water per liter of wine, although no description on methodology or source for this estimate is provided. Based on these numbers, the WASP program sets an (ideal) goal of consuming 1L water per liter produced wine among wine producers in Alentejo (Vinhos do Alentejo, 2018b). This is the only quantitative target of water use per unit of produced wine that was found among the studied programs.

4.3.4 IPW, South Africa

No quantitative nor qualitative data on member performance in terms of water management could be obtained, despite repeatedly requested by several actors connected to the program.

4.3.5 SWP, USA (CA)

The performance of SWP members is recorded by the CSWA and in 2015 a summary of the most recent distribution of members across the different categories for all assessment criteria of the Workbook was published in the Appendix of their sustainability report. The results for water management (vineyards and wineries) are provided in Appendix D. According to these graphs, in terms of vineyard water management members perform the highest on 'Irrigation system', where about 90% of members are placed in category 4. The second criterion in where the largest share of category 4 was achieved was the 'Filters and lines' criterion, where roughly half of the members scored a 4. The areas holding greatest potential for improvement (based on fraction of category 1) are 'Irrigation water quality' and 'Irrigation uniformity'. For winery operations, members appear to score lower, as the share of Category 2 and 3 are larger compared to vineyards. The worst performing areas in terms of winery water management were 'Storm water' and 'Cellars', while members performed best in terms of 'Water conservation planning and monitoring, goals and results'.

Studying performance over time, the sustainability report issued by the California Wine Community (CSWA, the Wine Institute and the California Association of Winegrape Growers) gives an indication of continuous improvement among members. The report is released about every five years, and in 2009 the obtained data showed an increase in member performance in over 60% of the workbook criteria compared to 2004 (California Sustainable Winegrowing Alliance et al., 2012). The most recent report released in 2015 does not give a quantitative indication of improvement, but conclude that most of the future program goals identified in the 2009 report were achieved, e.g. increasing and retaining participation of members and improving educational events, resources and tools (CSWA, 2015).

Yet, no quantitative records on average water use per unit of wine or any other indication member performance in relation to water management could be obtained. This is explained, according to Respondent 5, by that growers and producers are generally reluctant to share data. This is a culturally ingrained issue, and the CSWA has therefore agreed to allow growers to keep their data on site and only share it with the auditor, which is the primary reason why no quantification of water use (i.e. water footprint) could be presented here.

4.4 Barriers and drivers for improved water management

Here answers in relation to *RQIII* are presented, in where program representatives were asked what they perceive as key drivers and barriers for better uptake of water saving practices among wine producers within the scope of the sustainability program. The results are summarized below in Table 4-6, and presented more in detail in the text below.

Table 4-6: Summary of findings from primary data collection on perceived barriers and drivers for better uptake of water saving practices among members.

Country	Australia	Chile	Portugal	South Africa	USA (CA)
Framework	Sustainable Australia Winegrowing (SAW)	National Sustainability Code (NSC)	Wines of Alentejo Sustainability Program (WASP)	Integrated Production of Wine (IPW)	Sustainable Winegrowing Program (SWP)
Barriers	Time (workbooks, data recording); Perceived lack of financial benefits; Lack of education/information	-	Time (staff + producers); Level of awareness/education; Fear/lack of sharing (lack of) sustainability practices; Perceived lack of financial benefits; Culture	High costs linked to more efficient equipment	Lack of education/awareness; Perceived lack of financial benefits; Data sensitivity among members; Climatic differences
Success factors	Tracking progress over time; Identifying areas of improvement; Marketing sustainability practices	-	Member support - presence next to producers; Top mgmt engagement; Perceivable information sharing; Good dialogue b/w members and WASP staff; flip side of barriers	Experienced water use restrictions; awareness level[1]	Personal interest; flip side of barriers; Statewide environmental stewardship; Regional commitment; Member support; Program funding

[1] Author's interpretation of provided comment.

4.4.1 SAW, Australia

In terms of drivers for a successful sustainability program with high adoption of sustainable water management practices, the contact person from SAW identified a range of factors. Firstly, if growers can track their performance and see that they are improving from year to year, that could act as a motivating feature for better performance/adoption of practices. Moreover, as mentioned previously, members of the SAW program are required to keep detailed records of inputs on a wide range of operations for their production, which they report in the online self-evaluation system. Based on the collected data, members can compare their own performance to other growers in the region with help of the online program, which can help them identify areas for improvement, and further act as motivation for better performance. The last driver identified was that participation and good performance in a wine sustainability program might act as a competitive advantage for some growers, and could be used for marketing purposes.

In terms of reported barriers, Respondent 1 brought up lack of relevant education or information as a potential factor. She also mentioned that it might be difficult for growers to see a financial benefit from implementing more sustainable practices, which might act as a hindering factor for greater uptake of sustainable water management. Finally, the time for filling out the Workbook and for collecting required data could act as another barrier.

4.4.2 NSC, Chile

No data on this issue could be obtained during the interview, as the respondent was limited in time and had to leave before this question got the chance to be covered. Several follow-up emails were sent out with requested complementing information to two different persons at Vinos de Chile (including Respondent 2). However, no further information was given despite the repeated outreach.

4.4.3 WASP, Portugal

Respondent 3 stressed the presence and engagement of top management among producers in sustainability issues, including water management, as an important factor for improved adoption of sustainability practices. Apparently, many managers do not take part in the educational events, or are not actively involved in the sustainability work at the vineyard or the winery, such as in the reporting of performance in the self-evaluation system. This gives them limited insights into the benefits and importance of sustainability matters, which may lead to such issues being less prioritized in the company, according to Respondent 3. The respondent was under the impression that some of the top managers only take part in educational events just for the sake of ticking a box, without really listening or actively engaging in the workshops. In these instances, there is a great risk that what is communicated in the workshops will not be transferred or permeate further down in the company. Communication is a key success factor for improved adoption according to Respondent 3, who claims that the success in terms of sustainability work among some of their members can be directly traced down to a high level of communication among staff across different operations, i.e. where everyone is involved with everything. He further stresses the importance of internal communication in the context of workshops (which himself arranges), in where a dialogue between members, rather than him dictating information to the producers, is desired for greater uptake of information and knowledge sharing. Unfortunately this is difficult to achieve, as Portuguese producers often are reluctant to talk or share information on sustainability practices (including water management) for various reasons. Respondent 3 also discussed the way of communicating and interacting with the members. He believes that speaking in a perceivable way, where water saving practices are related to everyday life, may help with uptake of information, and consequently, implementation. He applies this to his

workshops, in where he stresses that one can apply the same rules for water saving at home in order to make environmental and economical savings.

Another success factor discussed during the interview was the degree of support that members receive. He believes that having good presence next to the producers is crucial for better uptake among members, i.e. helping them understand how and why they should implement water saving practices in everyday operations. He acknowledges that producers already have a lot on their plate, and that time might be an important constraint. Therefore the interviewee believes that the more you can do for the members, the better. For instance, he suggested that providing a template for a water saving program could act as important support, and a factor for greater implementation of water saving practices. Moreover, it is important to remind the producers that there are online resources and staff of the WASP program that are there to help in case they need support. However, it is a balancing act for the CVRA and the WASP staff to have the time and resources to educate and support the producers as much as they want. A final thing that was discussed as potential driver was the "mandatoriness" of a sustainability program, i.e. the legal status of practices relating to wine production and sustainability, e.g. in terms of water efficiency, pollution, use of pesticides etc. Reasonably, if there are stricter legal requirements, there will be a greater degree of adoption (Respondent 3). As the participation in the WASP program is voluntary (as most other sustainability programs), there is no forcing power available to get producers to implement recommended actions for a more sustainable production. However, WASP management plans to address this issue by in the future demanding members to partake and to achieve a certain level of performance in the program in order to become certified.

An important barrier for greater uptake of sustainable (water management) practices, apart from time constraints, that was identified was the level of education (or awareness) among producers. The less knowledge members have on sustainability issues, the less chance of sustainable production. It was also pointed out that the flip side of these factors could act as drivers (i.e. high awareness on sustainability issues and abundance of time). Cultural and climatic conditions also plays part in terms of degree of uptake of sustainable practices, the interviewee proposed, indicating that Portuguese people might be less prone to change and adapt to new information, e.g. in terms of sustainable farming practices.

And again, for a greater degree of implementation of water saving practices (and sustainable practices in general), top management needs to be involved to a greater extent – thus the currently experienced lack of engagement by the Boards of wine companies can be considered a barrier. It is believed that top managers need to see and understand the links between sustainable management and economical savings in order to ignite a drive for adopting sustainable practices within the company.

While discussing barriers for improved adoption of sustainable practices, Respondent 3 put the subject into larger context and pointed out that this in the end the issue comes down to a need of restructuring the whole education system. *"Education on sustainability and the environment needs to become integrated into everything, in all subjects. […] The commitment level [of managers] is directly connected to the level of environmental education. With the current education system, future managers will come out of school caring little about people or the environment, unless it saves them money".*

4.4.4 IPW, South Africa

In the case of South Africa, a perceived barrier of increased implementation of sustainability practices include the (usually) high costs involved in getting more efficient systems benefitting the environment, which may particularly constrain growers and producers with limited financial resources (Respondent 4).

No specific drivers were provided, however the contact person underlined that the awareness level on water scarcity of South African wine producers is generally very high, as the country has repeatedly suffered severe droughts in the past years, which has resulted in stringent water restrictions. Thus, South African farmers have become very knowledgeable on the practicalities and importance in managing water in an efficient manner and to farm with as little water as possible (Respondent 4). With this said, climatic conditions, experiences of water use restrictions and the awareness level on water limitation issues could be interpreted as being influencing factors or drivers in terms of how well farmers manage their water.

4.4.5 SWP, USA (CA)

As a response to what drives the adoption of sustainable management of water resources, Respondent 5 answered: *"At the end of the day, I believe it boils down to personal interests, but I also think there's a correlation to education and awareness and understanding that sustainable practices can save you money over time, for instance through water saving", adding: "When people start to see the bottom line benefits, that's when the interest [in sustainability issues] really peaks*". Still, she points out that the producers in the Californian wine industry are great stewards of the environment and it is part of the ethos in the state of California, often experiencing droughts. With that said, she believes that local climatic differences may take part in the level of sustainability commitment among producers, as in if water resources are scarce, producers generally tend to be better with managing water efficiently.

While underlining that it is difficult to pinpoint exactly what the different ingredients for a successful sustainability program with high adoption rates are, she strongly believes that regional commitments to sustainability do have an important impact on the level of uptake of sustainability practices - especially referring to recent public commitments among leaders in the Sonoma winegrowing association to certify their whole region as sustainable by 2019, which has resulted in fast and widespread adoption of sustainability practices (largely using the SWP to achieve their goals). Apart from public commitments, Respondent 5 told that the association of winegrowing in Sonoma also has a whole team focusing on "hand-holding", i.e. sitting down with growers to go through their self-assessment, which she believes also plays part in terms of degree of adoption of sustainability practices. Moreover, she acknowledged that the amount of funding a sustainability program receives influences its outcome too.

In terms of barriers, the respondent once again highlighted the fact that growers generally have a fear of sharing detailed, quantitative data, which may impede understanding of water use and where improvements need to be made. She connects this resistance in data-sharing to producers' fear of increased prices, as a result of greater transparency in the supply chain on resource use: *"There are many retailers asking for detailed information in the whole supply chain, and wineries have a really hard time to obtain such information from the growers as they are afraid that retailers will adapt the prices accordingly once they see how much resources are being used or applied"*.

It was also recognized that the flipside of the success factors discussed above may also act as barriers, e.g. lack of personal interest, education and understanding of how sustainability practices can lead to economic savings (Respondent 5).

5 Analysis & discussion

The following chapters are structured as follows: In section 5.1, findings for the respective sustainability programs are first compared and reflected upon with respect to the respective *RQs* in relation to findings presented in the literature review. From here emerging patterns are summarized and then discussed in a broader context, seeking to address the overarching research question. The conclusions chapter summarizes the most important findings from this research and also covers a discussion and evaluation of the research and analysis conducted as a whole, highlighting contributions to this field of research, as well as shortcomings of the study.

5.1 Analysis and comparison of programs

5.1.1 Program design and assessment methods

From the presented findings, it can be generally concluded that there is variation in the design of the investigated sustainability programs including *how* members are assessed on performance as well as *type* and *amount* of assessment areas relating to water management, although many similarities were found. All of the investigated case study objects are built up around a central Workbook or guidelines for members to evaluate their sustainability performance against, including issues relating to water management. The highest achievable level (if present) of the assessment criteria in these protocols typically reflects contemporary best practices in the field of sustainable vitiviniculture (SAW, 2017a; Respondent 4 & 5).

From studying program descriptions, protocols and by talking to key persons within the different sustainability programs, it becomes clear that the central documents that act as a basis for member assessment are strongly grounded in contemporary research from universities and research organizations, but also builds on input from industry experts, local vintners and growers, international branch organizations (such as guidelines from the OIV and FIVS), as well as on content from other sustainability programs. Yet, variances in robustness of program material were observed, where the SAW, IPW and SWP programs appeared more thorough, with especially strong contact with practitioners and research - possibly as they have been in operation for a longer period of time compared to the other two programs. It should however be pointed out that limitations of insight into program content of NSC prevailed due to legal restrictions in sharing parts of the program content. It applies for all studied objects that program content is frequently revised in order to ensure that criteria remain relevant and are based on up-to-date best practices, however this appears especially true for the SAW and SWP programs based on the information obtained.

Looking to similarities in terms of structure and content, all the case study objects did a clear distinction in their Workbooks on vineyard *vs.* winery operations, except for SAW, in where the scope is limited to only entail vineyards. Water is a central issue in all the sustainability programs, and in all cases applicable, members are assessed on how they manage their water both with respect to grape growing (vineyard) and wine production (winery). The most common assessment criteria for vineyard water management found among the investigated programs were irrigation/water management strategy for avoiding excessive water use; regulation of water quality; irrigation system maintenance and water volume monitoring. Most programs also included assessment criteria on control of water source and irrigation scheduling.

Studying number of areas that are assessed in terms of water management, the programs of SAW, SWP and NSC appear to be similarly thorough with respect to total amount of assessment criteria for vineyard and winery practices, respectively. Again, WASP has a similar

structure and scope to the CSWA program, but only assesses members on four areas relating to vineyard water management, reducing their overall "breadth" in terms of assessment criteria. A qualified analysis of the "breadth" of the IPW scheme is difficult to make here as the way central documents and their respective assessment criteria on water management are structured is very different compared to the other programs studied, as described in section 4.1.4. Taking on a broader perspective by looking at the fraction that "chapters" (or the like) on 'water management' cover as a whole in the workbooks of the sustainability programs studied, it appears a relatively similar amount of consideration is given to water issues, as assessment criteria on water management as compared to the total amount of criteria range between 10%-14%[1].

Comparing assessment methods, findings show that all the programs use a system of self-assessment for their participants, typically as an online tool, directly based on the program 'Workbook'. A third party regularly validates the entries from the self-assessment, often being staff of the program such as a Sustainability Manager or the like. Four out of the five studied sustainability programs have an accredited third party certification mechanism as part of the program (SAW, NSC, IPW and SWP), while WASP is being underway implementing such a certification scheme, which is expected to be in place by 2019-2020. In these instances, members typically have to fulfill more demanding requirements, or a set of 'critical' criteria or a certain percentage of the total score (SWP, NSC and IPW). Only SAW allows members to be certified in a certain category (red, yellow, green or blue), in contrast to the others in where members are either just enrolled to the program, or certified under the requirements as set out in a program standard. While having an accredited certification body auditing member practices might seem as a good means to strengthen a program and its legitimacy, the results of Flores (2018) did not indicate that including a certification or label option impacted on the "learning potential", i.e. improvement capacity of the sustainability programs investigated. SAW was the only program that reported having a system enabling members to compare their performance against other growers in the region, to state and national benchmarks, or even vineyards under similar climatic conditions; while information from Respondent 5 (SWP) indicated that at least a comparison between performances of members can be made.

There are different approaches to performance monitoring and differentiation, in some cases explained by differing business strategies in how to get more members on board of the programs and encouraging greater uptake of sustainability requirements (Respondent 2). Only the NSC does not distinguish between better or worse performing members, i.e. excludes different levels of the self-assessment. Instead, the program is designed so that members have to fulfill demanding critical criteria, as well as a certain percentage of the total score (60%) to become certified. IPW are similar in that sense by also requiring a certain percentage (65%) of the total for becoming certified under the program. In this way, high standard, legitimacy and reputation of the certification and the program is maintained, according to Respondent 2 at Vinos de Chile.

In relation to program content, it can be deduced from the answers provided that there is no universal agreement on what is considered 'best practice' in terms of water management for winery and vineyard operations, as this was reported to be region, climate and production dependent (Respondent 2, 4 & 5). This might also explain why there appears to be no international document detailing best practices, but are rather kept general such as the FIVS and OIV guidelines on sustainable wine production. However, generally it appears that the most difficult level to achieve within the respective programs typically is designed to reflect what is considered "best practice" (Respondent 1, 3 & 5).

[1] This number is difficult to obtain for IPW due to the nature of the guidelines as described before.

The SWP program of California appeared most stringent in terms of requirements for becoming certified, looking to number of actions required. Apart from reaching at least a minimum category 2 of all assessment areas in the Workbook, SWP members also have to demonstrate continuous improvement, identify priority areas and create action plans accordingly. NSC of Chile also appears robust in terms of certifications requirements, given their demand on continuous improvement as well as their high score bar (60% of total score, as well as all critical criteria) set for members to become eligible for certification. IPW also have a high threshold for members in terms of required total score but does not require demonstration of continuous improvement, while the SAW program appeared to have less demand on their members in order to become certified, especially given the lower certification levels available (i.e. red and yellow levels).

To determine which means of structure and strategy for certification should be considered superior or more demanding than other programs is deemed unfeasible due to the limited insights and capacity of comparing the specific requirements of each assessment criteria under the respective programs. What can be generally hypothesized however is that the more frequent the third-party audits are (both validation of self-assessment entries, as well as accredited third party audits for certification); along with the presence of a requirement on continuous improvement for keeping the program certificate – chances that members will actually improve their performance in terms of water management over time are likely to be higher. Based on this, SAW, NSC and SWP are more likely to improve average member performance over time, as they all hold a requirement on continuous improvement, and also have annual third-party checks of member reporting in the self-assessment system. However, their reference base level of assessment criteria may vary in degree of difficulty to achieve, reducing the robustness of the previous claim.

5.1.2 Member support for improved water management

Findings show that all of the studied sustainability programs do provide support for members (of varying extent) for increased adaption of sustainable management of water resources, apart from the instructions/criteria given in the respective Workbooks. Means of member support varies, although the most common type of support that was reported by all of the programs was arrangement of educational events/workshops in where members are invited to learn about a specific topic in relation to of wine growing and production (such as water management, energy efficiency or soil health). In these kinds of events members typically are encouraged to share personal experiences and best practice in regard to the topic covered. Findings further showed that most of the objects studied have, apart from the workbook itself, some complementary material or supporting documents (such as practical guides, relevant articles or links to informative sources) relating to the Workbook material - which in many cases relate to irrigation or sustainable water management in general.

Although members receive assistance in implementing assessment criteria and improving water resource handling in all the investigated cases, programs that have been around for a longer time (particularly the SWP) appear to have a more robust arsenal of supporting documents and other material for members to use for these purposes. The SWP have especially impressive ambitions to give members direct and tailored feedback on how they may improve through the use of the new software that is currently underway. Moreover, they were the only program who actively reported that they have experimented with different media, times and settings of the targeted educational events in order find successful concepts as well as patterns of when members are more likely to attend. Lastly, the amount and type of available resources for supporting members in adoption of sustainability practices were a lot more thorough than found elsewhere. These observations of the SWP program are also in line

with findings from Flores (2018), in where the many means of member support by the CSWA were highlighted.

The Sustainable Australia Winegrowing program is unique in that sense that the MVGWTA has a vineyard used for educational purposes for its members, and also has created a 'Viticulture reference group', focused on meeting needs of individual growers and facilitating implementation of sustainability practices through different channels. The educational events are reportedly based on the knowledge gaps emerging from the self-evaluations conducted by members, which most likely increases the likelihood for relevant content and support for members through these events.

Information for the NSC and the IPW was highly limited by the lacking accessibility of program representatives and deficiency in information available online. However, Vinos de Chile reported an interesting approach of assisting poorly equipped members, lacking financial resources in order to lead a sustainable wine production, in terms of providing governmental subsidies for meeting requirements of the NSC. The IPW program of South Africa was reported to not hold any official documents intending to support members with adaption of sustainable water management, apart from the manuals. Some links and resources are provided on the website, however none of these sources appeared to have a direct connection to water management. The only extracurricular source provided to members in relation to water management was the material of the water stewardship program from the WWF, whom they partner with.

Members under the WASP program receive a lot of support from the one employee for the program, as well as from the available documents and manuals in the online member portal used for self-assessment. However, the limitations in manpower likely means less overall support for members compared to other programs. Yet, this cannot be quantified or confirmed with the data provided.

Generally, however, the studied programs as well as the wine industry as a whole appear to be highly aware about the importance on careful handling of water resources and already do a lot in order to save water and improve water quality, which is supported by findings in e.g. Christ & Burritt (2013); Flores (2018); Corbo et al. (2014); Medrano et al. (2014) and Santiago-Brown et al. (2014a).

The literature review conducted found no study devoted to investigating different means of support and their respective success over time for improving member performance in terms of sustainability practices within the wine industry. Neither did information collected through interviews reveal which means of member support is the most successful, although workshops/educational events in where members can share their own insights and experiences appear to be a popular and appreciated concept that is working well. Still, based on the findings, no solid conclusions can be made with respect to which methods are the most preferable for improving uptake of water saving practices. This issue would be desirable to investigate in future research, however, the dynamic nature of the programs and their constant development over time, the time required to measure/detect effect of support action, uncertainty around interdependency, as well as the limited time that many programs have been operational might act as an important challenges for this type of research.

5.1.3 Reported performance

In terms of performance per se, none of the programs were able to provide quantitative estimates on (average) water use per unit grapes or wine among members, as desired, which directly inhibits direct comparison of water use efficiency among programs. However, data on

member performance, in terms of distribution within different assessment categories (given in percentages), were given in three out of five cases (SAW, WASP & SWP). All of the interviewees reported large variance on member performance with respect to sustainability practices, including water management, within the respective programs. These quantitative estimates further indicate that there is large variation between program, both in terms of what is assessed, and reported performance.

In the three cases where indications on performance in vineyards was reported, 'irrigation system' was the assessment area in where all programs performed the best, whereas performance in terms of 'water quality' (for irrigation) was the area in where all the programs scored the poorest (SAW, 2017a; see Appendix C & D for comparison). The report of SAW indicated that 'Water Management' is the chapter in where members scored the highest on average compared to other environmental sustainability criteria. This was not the case in the WASP program, in where instead disease and pest management in cellars was the best performing area (in 2017). In the chapter on water management in the vineyards members scored 3.25 on average and 2.5 for water conservation in cellars (on a scale from 0-4) for the same year. Based on the data provided in Figure 4-2, the average score in 2017 is estimated to 2.9, with all chapters included, making performance in terms of water management at vineyards slightly better - and water conservation slightly worse - than average scores indicating overall member performance. No statistics allowing such comparison was found for the SWP program.

In terms of the wineries, most assessment criteria relate to measures for water reduction in the different operations for wine production. WASP and SWP have almost identical areas of assessment for the wineries, including planning, monitoring, goal-setting etc. on water conservation and water quality, but also on means for water reduction in specific winery operations/areas such as crushing, pressing, tanks, filters, barrel soaking, landscaping, bottling and general cleaning. All the programs having winery operations within their scope have assessment criteria relating to wastewater discharge and quality. Especially IPW has a comprehensive list of requirements relating to wastewater management. Performance wise, data for wineries was only given for SWP and WASP (as SAW does not cover wineries), and these data indicate that the assessment areas in where members perform the worst are for the SWP 'Storm water management' and 'Cellars' and for WASP the criteria on 'Water conservation planning, monitoring, objectives and results' as well as 'Storm water management'. Members of SWP, in contrast, perform best in the assessment area of 'Water conservation planning, monitoring, objectives and results', with about 45% of members being placed in category 4 (i.e. the most difficult category to reach), while WASP members perform best in the areas of 'Septic hosts/water treatment stations', 'grape recovery', and 'pressing operations' – looking at the fraction of members placed in the highest category (again, consult Appendix C & D for comparison). WASP was the only program for which a quantitative goal of water use for wine production in wineries was set (1L consumed water/L produced wine), which could potentially act as a reasonable goal for water use under other programs too, especially since winery water use is not affected by climatic differences, making this estimate more transferable.

By studying the graphs showing performance distribution for these two programs, it appears that water management at the vineyards are generally better than at the wineries, based on the fraction of producers in the lowest performing category. The SAW program only provides member average, thus there is no insight into the distribution among the different performance categories.

It should be noted that only two of the programs had the same amount of levels for allocating members among different performance categories (SWP and WASP), making a fair comparison based on performance categories or scores difficult. In addition, these two programs had different required percentages of total assessment score related to the corresponding categories, further complicating comparison. And, even given the allocation scores would be identical among all programs, it is expected that the actual difficulty level to reach a certain score will vary. Thus, it is considered subjective and inequitable to directly compare percentages on reported performance between different programs, especially as content and assessment areas between the different study objects vary largely. Yet, it was the only indication of how well members are performing in terms of water use efficiency and was therefore used for analyzing and discussing data in lack of better alternatives.

Neither NSC nor IPW representatives could provide any data on average water use performance, or performance distribution of members (NSC for reasons given in section 4.1.2.), limiting comparison and analysis of program differences and similarities which could be used for drawing conclusions on successful program concepts for greater adaption of sustainable management of water resources.

Despite none of the investigated programs were able to provide quantitative estimates of average member water use per unit produced wine; some of the interviewees reported that they have ambitions to collect such data in the future, and that they are currently underway working towards greater use of quantitative estimates and indicators (Respondent 3, 4 & 5). Being able to provide quantitative estimates of total water savings achieved through the sustainability program over time might be highly valuable for both internal and external stakeholders, and might also increase likelihood for obtaining state or regional funding for the continuation of the sustainability program, in case significant water savings can be demonstrated (Angel et al., 2018; Santiago-Brown et al., 2014a). Again, the SAW and the SWP program does allow its members to compare their performance to program peers. SAW has wider possibilities in terms of comparison, allowing members to compare with peers under similar conditions (size of vineyard or climatic zone) and with state, zonal, regional and national benchmarks (including quantifications of water use), under Entwine Australia (AWRI, 2018). This type of system allowing for comparison is considered highly useful (particularly the possibility to compare individual performance against members under similar climatic zones), since benchmarking allowing for competition may be an important inducing factor for improving practices (Flores, 2018),. Alas, no such advanced system for comparison was found for any of the other investigated programs.

As can be concluded from the very few quantitative estimates on water use from wine producing countries relevant to this study (presented in the literature review - Chapter 2), there are large variations with respect to methodology, use of system boundaries as well as quantitative approximations, which is also supported by the extensive review article of Ferrara & De Feo (2018). The quantitative estimates reported by Engel et al. (2015) for Alentejo, Portugal should be interpreted with care as numbers were provided by regional wine producers, from where no specification on system boundaries or methodology for these estimates were given. In other words, these estimates may not be very accurate and have not been established in peer-reviewed academic papers. Overall, findings indicate that water use in relation to winery operations ranges between about 0.5L to 14L per L produced wine, while for vineyards estimates ranged between 88-264L/L produced wine. Again, however, the use of system boundaries and way of reporting vary to such a large extent that findings from the literature review on quantitative estimates of water use in connection to wine production within the studied countries are not considered robust enough in order to draw any conclusions on variances or superiority among countries in terms of water use efficiency per

comparable unit, (e.g. bottle or liter of wine produced). However, best practice of water use in wineries have been reported to range between approximately 0.5L - 1.6L water/L produced wine, which might act as a useful guideline when setting quantitative targets for water use in relation to winery operations. Also reported in the literature review were estimates on proportion of the green, blue and grey water footprints in relation to wine production. These findings demonstrated that the green water footprint is by far the largest one of the three, indicating that this might be of particular interest to focus efforts on greater water efficiencies.

5.1.4 Barriers and drivers

The most commonly reported barriers for improved member performance on water management issues (and sustainability issues as a whole) were lack of education and/or awareness (reported in three out of four answers); lack of time; and perceived costs/lack of financial benefits. Other barriers that were brought up included resistance to share information/data, culture and climatic differences among members. The answers obtained in with respect to barriers were relatively homogeneous, while answers on drivers had a wider spread.

Only in two cases there were overlapping answers given by the interviewees with respect to success factors/drivers for improved adoption of sustainable management of water resources among members. These answers were the importance on member support, including close contact and good dialogue with members, which was reported by representatives from both WASP and SWP, who also recognized that the flip side of the identified barriers could also be considered drivers. Other drivers mentioned included using sustainability performance for marketing purposes; proven financial benefits of sustainable practices; as well as public regional commitments on sustainability by industry actors. The importance of top management involvement in sustainability issues for achieving sustainable water management in wine production was another factor stressed among one of the interviewed representatives. And, as pointed out by the SWP representative, the degree of commitment often boils down to personal interests among producers. She also said to believe that there is a correlation to education and awareness and understanding that sustainable practices can save you money over time, for instance through greater water efficiency.

The drivers and barriers to increased adaption of sustainability practices (in this case sustainable water management) as identified by the interviewees cohere well with the reported findings in literature, suggesting that the interviewees are well informed and have a sound and accurate perception of which factors influence adaption among producers. Notably, the perceived impact of personal, environmental values and attitudes are well-aligned with findings from Gabzdylova et al., (2009) and Marshall et al., (2005), while barriers such as time and perceived costs match with findings of Santiago-Brown et al. (2015) and CSWA (2009). The identified driver of ability to compare sustainability efforts with peers (in relation to industry benchmarks) as an incentive to improve performance, were also in line with findings of Flores (2018). Also when looking outside literature findings specific to the wine industry, the reported influencing factors of environmental awareness and personal values on adaption of sustainable behavior have strong support in other literature (e.g. Rex, Lobio & Leckie, 2015; Quazi, 2003; Mzoughi, 2011). The importance of top management involvement as for adoption of sustainability practices among growers and vintners as pointed out by Respondent 3 also has report in previous research (Johnson, 2015). Unfortunately no answers were obtained from the (two) contacted persons at Vinos de Chile on drivers and barriers, and only one barrier was pointed out by the representative at IPW, limiting the validity for generalization with respect to *RQIII*.

5.2 Approaching propositions on program design and managerial means for improved adoption of sustainable water management

This section summarizes the most important insights from the discussion and relates these to the overarching research question of the study on how vitivinicultural sustainability programs can work to improve adoption of sustainable water practices among their members.

Findings show that some programs have greater coverage of assessment areas, looking to the sheer number of assessment criteria. Although no comparison of the specific requirements of these criteria was made, it is hypothesized that overall water management is more likely to be better in a program having a broad set of assessment criteria (e.g. covering origin of water, water quality, water efficiency, end-of-life treatment etc.). Based on this, it is suggested that those sustainability programs assessing members on fewer areas with respect to water management could take inspiration from those with a broader set of criteria in order ensure that no essential areas of water management is overlooked. Moreover, by having assessment documents with strong support from research, local practitioners (growers and vintners) and international guidelines of industry branch organizations, chances of efficient and locally optimal water management are increased. As technical improvements readily occur for e.g. irrigation systems or winery processes, it is important for wine sustainability programs to always stay updated and frequently adapt their assessment criteria, educational material, recommendations, supporting documents and industry benchmarks accordingly.

In three out of five cases, programs required members to demonstrate continuous improvement, which is a requirement that could be recommended for all sustainability programs to adopt, as this increases chances for enhancing overall performance over time. Based on collected information, it is hypothesized that having a high frequency of 3rd party audits, both in terms of internal validation-checks on member entries into the self-assessment system (i.e. by a program representative), and by accredited third party certification bodies; program participants will experience greater pressure to comply with water management requirements and maintain good practice in between audits. Programs are encouraged to ensure high minimum requirements to become certified, based on the demonstrated needs of improved water management within the industry (Medrano et al., 2015; Christ & Burritt, 2013), as this would increase the chances to improve overall water management within their program scope. However, this must be balanced against realistic expectations on producers and their capacity of achieving such requirements, as if these are too high, programs may run the risk of losing members. It is believed that including certification and a label in the program (assuring sustainable practices) is beneficial as consumer awareness and demand on sustainable production is increasing, making this also a potential competitive advantage (Schäufele & Hamm, 2017; Respondent 5).

Findings revealed that program structure and means of assessment vary between programs, and, partly due to the absence of quantitative records of average water use among members no strong conclusions on which structure is superior with respect to increasing chances for improved water management can be drawn. However, findings from Flores (2018) and Santiago-Brown et al. (2015) indicate that program capacity is not directly related to program or framework structure but rather has to do with stakeholder engagement and the individuals driving the development of the program. Therefore, developers of wine sustainability programs may gain more from carefully choosing the people managing these programs than from being occupied with details on program design.

In terms of member support, providing practical examples and suggestions on improvement may be efficient means of improving learning potential and consequently performance,

according to findings of Flores (2018). Thus, the means of member support provided by the SWP, as in practical guides and instant feedback (i.e. tailor made suggestions on improvement in the online portal for member self-evaluation) could be considered good practice for increasing chances of improved member performance, and may act as inspiration for other sustainability programs. The SAW program instead provide "tailor made" support in a member-wide sense, as they develop their educational events based on the average outcome of the self-evaluations, which is likely to increase relevance of educational material and support. Overall, workshops and educational events focused on improved water management appear to be a successful and appreciated means of support used by all sustainability programs. However, as mentioned before, it was stressed by one interviewee that greater engagement by top management in these events is needed in order for recommended sustainability practices to gain priority within wine companies. To gain top management interest for sustainability issues (including efficient handling of water resources) it might in this case be necessary to demonstrate financial benefits for adopting sustainable water management practices, as this was reported an important barrier of by several interviewees. It might be inspiring for both managers, growers and vintners to hear "success stories" from other producers of perceived environmental and financial benefits from e.g. optimizing water use or improving wastewater quality (Santiago-Brown et al., 2014a). This could potentially also attract non-members and increase regional adaption of sustainable practices.

Other actions that might stimulate adaption of sustainable water management include lightening the workload of wine producers and managers and minimizing the associated time of implementing sustainability practices, e.g. through providing action plan templates, manuals for improvement and other forms of supportive material – as time restrictions was another commonly reported barrier for greater uptake of recommended water management practices. It can also be concluded, both based on interviews and findings in literature, that the degree of prior education/awareness on sustainability issues among wine producers is a key-determining factor for the level of commitment and adaption of sustainable practices. It is therefore hypothesized that members who receive a lot of support in terms of education, time and practical material are more likely to perform better in terms of sustainable water management.

Financial resources for the management of vitivinicultural sustainability programs also play part in the amount and quality of support that members receive, and consequently their ways of managing water resources. Thus, ensuring availability of staff that can handle funding requests or other efforts for monetary support is also important, as pointed out by one of the interviewees. Following the example of Chile, greater efficiencies in regional or national water management among wine producers could be reached through governmental subventions on water-efficient equipment, e.g. expensive irrigation systems, (especially for small-scale farmers, lacking financial resources), in case it lays in national interest to use less freshwater and there are resources to do so.

Overall, findings suggest that there is a lack of quantitative records of water use among members in relation to wine production both at vineyards and wineries. This could also be seen in the literature review, considering the very few estimates on water use found in the context of wine production in the countries picked for this research. More so, there was large variations in use of method and scope in these estimates on water use, further reducing the meaningfulness of the results provided. SAW was the only program allowing internal comparison of performance (including water use) against a broad set of reference parameters. Findings from the literature review suggest that the possibility to compare individual performance against benchmarks might induce a feeling of competition, triggering action and improved practices. Thus, such a system allowing comparison of industry benchmarks could be useful for other sustainability programs to adopt as well.

6 Conclusions

This section covers the most important insights from the discussion in relation to the overarching research question of the study. It also presents how this piece of research adds value to academia and identified audiences, discusses the relevance and limitations of the study, and provides suggestions for future research.

Approaching the overarching research question '*How can vitivinicultural sustainability programs improve adoption of sustainable management of water resources among their members?'* some valuable insights can be found in the answers obtained through *RQI-III:* The investigated vitivinicultural sustainability programs were found to employ extensive measures for improving water efficiency among program members. In all cases, a system for self-assessment against a set of criteria on water management in the vineyard and in the wineries was found, typically summarized in a program 'Workbook'. All programs have annual third-party validation checks (often conducted by program staff) to ensure that reported entries to the system reflects the reality, and in four out of five cases (soon five out of five) a certification mechanisms was in place, in where accredited third-party certification bodies conduct audits against a certification standard. However, frequency of these external audits varies among programs. Assessment areas with respect to water management varied both in terms of number and amount among the studied cases, with a range of 4-15 assessment areas for vineyards and 10-16 for wineries, however areas of assessment remained largely similar. All programs examined provide extra support for members for improved adoption of sustainability practices; most commonly through hosting educational events, work shops, and through supplement material such as practical guides, manuals and links to informative resources. Some programs appear to be more advanced in this respect, especially those that have been operative for a longer period of time.

The studied programs collect data on water management performance of members in different ways. Indicators used for assessing performance turned out to be largely qualitative, and no quantitative estimates on water consumption per unit produced wine could be obtained from any of the investigated programs. Still, three of the programs are keeping detailed results of the distribution of members within different performance categories (with respect to different sustainability practices covered in their respective program Workbooks), based on the reported performance in the self-assessment system. The two other case study objects gave no indication on member performance, for varying reasons. Yet, from the obtained results it can be concluded that wine growers perform best in the areas of irrigation system and maintenance, while results suggest that efforts should be focused on improving irrigation water quality, as this was the worst performing category in all of the three reported cases. In terms of winery operations, results varied between programs but overall the area of storm water management holds particular potential for improvements. Members of SWP perform best in the area of 'Water conservation planning, monitoring, objectives and results', while this was one of the weakest areas of WASP members. Compared to other sustainability practices covered in the workbook, SAW members scored highest in the area of water management, suggesting a successful program design for large adoption of best practices in terms of sustainable water management. Data from the WASP program indicate that there is room for improvement both for water management in vineyards, but especially in wineries. The provided results of distribution among performance areas could be used for concentrating member support accordingly, e.g. through educational events (which one program reported already doing). Benchmarks of the industry, by region or even by climatic conditions has been reported to be used by some of the studied programs, which, in combination with practical guides on how to adopt best practice, has been considered good practice in previous studies as this appear to increase likelihood of improved performance.

Other program features protruding as good practices from the studied cases were a requirement on members to demonstrate continuous improvement. Such as requirement was found in three of the five examined programs.

Certain factors have been reported as important drivers and barriers in relation to increased adoption of sustainability practices, including water management. The interviewed program representatives considered lack of education/awareness on sustainability issues; time shortages; and perceived lack of financial benefits to be the most important barriers for improved adoption. Answers on perceived drivers/success factors for greater adoption of sustainable handling of (water) resources varied largely among respondents, however, member support - in where close contact and a good dialogue is kept with members was reported a key factor in two of the cases. Other drivers mentioned included "the flip side" of the identified barriers, as well as using sustainability performance for marketing purposes; personal interests among producers; public regional commitments on sustainability by industry actors; and the importance of top management involvement.

The reported factors affecting degree of adoption of sustainable practices had strong coherence with findings presented in the literature review, increasing the validity of these claims. As such, to adapt program design accordingly, e.g. ensure strong member support (especially in terms of offering relevant education and reducing the time members spend on implementing sustainability requirements, for instance by providing relevant templates and manuals); to demonstrate financial benefits and to work for improved involvement of top managers, speak of successful means for increasing chances of improved adoption of sustainable management of water resources among members.

6.1 Relevance of study

Detailed insights into how five different vitivinicultural sustainability programs in water stressed countries are actively working towards improving water use efficiency within the industry at management level have been given through this study. It has done so by conducting five in-depth case studies, interviewing program managers and consulting program material, and by carrying out a thorough literature review in the field of vitiviniculture, sustainability schemes and water management within the industry, using an exploratory approach. The study applied a wide research scope describing and comparing factors such as program design, assessment methods and criteria, means of member support, reported performance as well as reported barriers and drivers for greater adoption of sustainable water management.

As presented in the Introduction chapter, this research had four articulated aims, namely to:

1) Describe how a selected set of vitivinicultural sustainability programs situated in regions under water stress currently are working to improve water management among program members
2) Obtain estimates on water consumption per unit produced wine, and indications on members' degree of adoption of program requirements on water management, in order to relate this to the above query
3) Understand program managers' perceived drivers and barriers for improved adoption of sustainable management of water resources among members
4) Use insights from the above queries to identify successful means for improving adoption of sustainable water management among wine sustainability programs

The study more specifically intended to identify areas of successful program design in terms of program content, assessment methods and program member support by comparing these

issues between the selected wine sustainability programs. As described in the Methodology chapter, this information, along with estimates on member performance, as well as perceived barriers and drivers for improved adoption of sustainable water management, would help inform the sought aim on identifying successful means for improving adoption of sustainable water management. The research questions created for this study were designed so that each of these aims would be addressed.

With respect to the aims formulated for this research, the study can be considered effectively successful with respect to aim one and three, as substantial amounts of information were obtained in relation to these queries for largely all of the studied programs and their respondents, as well as from academic sources. In terms of research aim two, unexpectedly little data was available, both for the examined programs as well as from previous studies. At the commencement of this study it was hoped that estimates on water use per unit produced wine could be obtained, in where programs used the same methodology for these estimates - which turned out to be far from the reality. As this aim also included comparing these estimates to findings in relation to aim one; the lack in available data and the inconsistencies found in terms of methods applied for the obtained quantifications, considerably hampered the purpose and aims of the study. Yet, the estimates on member performance that were obtained provided valuable input and were sufficient to identify some emerging patterns and provide indications on where program efforts should be directed. Together with the abundant information achieved in relation to *RQI & III* (i.e. aim 1 & 3), the overarching *RQ* could be addressed with relatively high confidence, providing important insight into what vitivinicultural sustainability programs can do in order to increase chances for improved adoption of sustainable water practices. It should however be acknowledged that the findings obtained from interviews and literature relating to assessment and performance for the different sustainability programs are not sufficient for drawing any definite conclusions on which program design and means of member support should be considered preferable or superior for improved adoption of water efficient practices, primarily as quantitative data was lacking and the varying nature of program designs inhibited a fair comparison.

Yet, this research has provided valuable insight to the field of water management within viticulture, both through the extensive literature review conducted and through the case studies, which have brought unique insights from program managers. This is especially true in the case of Portugal, which appears to have been studied to a lesser extent than the other programs part of this research. As such, provided findings can be of great value for many actors. The literature review provided many useful insights to the field of factors affecting adoption of sustainability practices and confirmed the importance of reduced water use within the wine industry, adding to the relevance of the research conducted. Particularly less advanced wine sustainability programs, or wine regions/countries that are yet to implement a sustainability scheme are expected to benefit from these findings, primarily by avoiding beginners mistakes and learning from programs that have been around for a longer period of time. The study might be in special interest for (future) program managers in countries or regions currently under water stress, or are running risk of facing water shortages in the future.

Findings can also be of interest for the studied sustainability programs, which are under relatively similar climatic conditions, and are all facing water stress. Thus, the reported assessment criteria, program design and means of support for improving management of water resources from other programs may act as inspiration and have high applicability. The barriers and drivers for better uptake of sustainable water management identified through interviews and in literature can further assist program managers by taking these findings into account when developing program design and content.

Answers to the overarching *RQ* for this study might not only be of value for the wine industry but for other industries too, especially within the agricultural sector, as findings and suggestions brought out here cover general issues on program management and operational design for better implementation of sustainability practices - which is faced in almost any other industry. Findings might be of special value for other industries or companies having a sustainability program in place, however it is unclear to what extent the concept of sustainability programs exists in other sectors and industries.

Taking on a broader perspective, by putting vitivinicultural sustainability programs into light and demonstrating how they are currently working towards more sustainable water management within the industry and what challenges they are facing, interest might spur among policy makers and external stakeholders on how these issues might be overcome. Insights from this study might be of increasing interest as awareness on climate change, population growth and declining water availability grows, and as more people come to realize that in the end we are all part of the same hydrological cycle and that it is in the interest of everyone to manage freshwater sources sustainably.

6.2 Limitations and sources of error

While major efforts for obtaining the desired information have been made, it should be pointed out that in the case of Chile and South Africa, little information could be acquired in comparison to the other programs, especially in terms of performance data. An interview was held with a program representative from Chile, but not all the desired information could be obtained during the limited time of the interview, and requested documents were not provided. In the case of South Africa, no Skype interview could be arranged, despite repeated tries with several different persons related to the IPW program. However, most questions of the interview guide were answered through email instead. Yet, compared to the other case study objects NSC had limited information available online, many details were instead collected from other academic papers. This also applies to IPW, which had limited material and information of the program online. No interview could be arranged with representatives from SAW within the given research period, however, thorough answers to all the questions of the interview guide were provided, together with a handful of supporting documents. Therefore, this study is considered to be mainly limited in the cases of NSC and IPW, which should be borne in mind when reading this study. With this said, the amount and character of collected data from wine growers and producers varied strongly among the studied sustainability programs. In some cases, careful records of the distribution among different performance levels were available, while in other cases no such information was available, due to different nature, design and/or philosophy of the program. These differences limit the comparability of data, but transparency has been sought throughout the study to reduce this limitation. Differences in program size is not considered a major constraint for the purpose of this research, as it seeks to study how different wine sustainability programs are operating with respect to water management, which does not necessitate homogeneity between programs. However, program size may be of importance when looking into aspects such as member support, as staff availability might be more or less restricted due to this factor, which might in turn limit comparability and should also be taken into account when interpreting the results of this study.

As findings are primarily based on what was reported by one program representative for the respective programs, there is an inherent risk of information being subjective, and subject to personal perceptions, opinions and traits. For instance, some interviewees might have been more prone to talk enthusiastically about program efforts while others might have been describing program efforts in a more modest way, which might have an impact on result interpretation. Moreover, in the case of SAW, the questions covered in the interview guide

were provided through email, as no Skype interview could be arranged – giving this representative more time to think and thoroughly answer the stated questions, compared to representatives interviewed through Skype who were limited by time and had to answer immediately.

In terms of data analysis, interviews were transcribed manually and only what was considered relevant for the purpose of this research was presented in the findings section. As content was analyzed qualitatively and not coded using quantitative methods, there might be a slight risk of subjective interpretations of information provided. However, interviews were rather short and few, and listened carefully to, thus the risk of misinterpretations is considered low. Continuing reflections on data analysis, it is recognized that the amount of assessment criteria on water management is not an exhaustive indicator of program requirements – however, given the amount of programs, their amount of assessment criteria and their individual requirements for specific performance categories/levels (up to five different levels), this indicator was considered a more approachable approximation of assessment coverage.

As mentioned in the introduction chapter under limitations, this study chose to not look closely into technical details on water management, but rather to examine the investigated sustainability programs with respect to management and program design. This also applied when comparing assessment areas relating to water management, where the number, as well as the topic of assessments was compared. However, in order to gain a greater apprehension of how the different case study objects "in depth" works with water management, the actual requirements for each assessment criteria would have needed to be compared, and preferably taking different categories/levels of the programs into account. Such information might have added value in terms of insights into variances in practices and levels of requirement, in order to better understand how advanced the respective programs are, and to better concretize how technical approaches towards water management differs among the studied programs. However, within the temporal scope of this research, this was considered unfeasible.

Again, this study initially intended to compare quantitative estimates on water use (e.g. through water footprints or estimates from LCA studies) between the different sustainability programs, which could give indications on which program has succeeded better with achieving resource efficient water management among members. This, in turn would be used for investigating by which factors these differences could be explained (such as member support or program design), for suggesting adaption of these practices by other programs. However, as findings show, the investigated sustainability programs are currently not keeping records of such estimates, or were unable to provide them. This lack of quantification forced analysis of data to only rely on qualitative estimates, which limits the robustness of claims and hypotheses around the reported findings.

6.3 Suggestions of future research

A few knowledge gaps have been identified throughout this research (of which some have been briefly touched upon in the text), from where suggestions for future research are suggested. These suggestions are outlined below.

In order to generate more meaningful findings, as well as for reasons of tracking performance over time and enabling estimates of total water savings and water use, it is suggested that objective quantifications of water use among wine producers and its environmental impact should be created, following recommendations of Costa et al. (2016). For this to bring any value, it would be critical to use the same, standardized methodology when estimating water use, taking climatic and other necessary factors into account. A suitable option would be the methodology for estimating a Water Footprint developed by the Water Footprint Network,

which takes freshwater availability into account (Ercin & Hoekstra, 2012), enabling a more fair comparison. This would not only allow for a more meaningful comparison between programs, but also for benchmarking, which in turn could trigger competition. More importantly, quantifiable data on actual water use per bottle produced or per kilo of grapes would allow for more legitimate claims on superiority of a certain program, which consequently could be used for drawing conclusions on successful program concepts and means of member support.

In relation to *RQII*, an underlying query coming out of this research is which means of member support can be considered the most successful, or efficient for greater implementation of sustainable water management? In other words, what means are the most efficient for igniting members' adoption of sustainable behavior in the context of wine production? Is it education, hand-holing, or personal interest? These questions were slightly approached in this study, but it would require an extensive research project over a long period of time, in where different means of member support are tried while studying how this impacts adaption, before any conclusions on this topic could be drawn.

As mentioned in the limitations section above, this study did not look into technical details or compare specific criteria of water management across different levels among sustainability programs. However, doing so could bring valuable insights, as discussed above, and could be explored in another study.

A need for greater adoption of quantitative estimates on water use has been repeatedly expressed in this research. However, knowledge on wine producers' perception on this suggestion is limited. As Respondent 5 pointed out, resistance to data sharing among producers could have to do with fear of adjusted prices according to resource use. This suggests that unless there are requirements on quantitative reporting of resources use (e.g. in a certification standard), there might be not enough incentives for wine producers to share their data if that is to affect them negatively in terms of increased prices. However, this was only expressed by one respondent and might not apply in other countries. Yet, it would be of interest to investigate this issue further to better understand barriers to adoption of use of water footprint reporting.

This study focused on five countries that are under water stress to a varying extent. However, it could be of interest to look into how water use and water saving practices vary between wine producing countries that have great abundance of water, in order to examine whether average precipitation have an impact on attitude and handling of water resources.

Lastly, in the scope of this research, only agronomic and technical practices for improved water management has been discussed, and primarily from a management point-of-view. However, as mentioned in the introduction, there is another "branch" of research for approaching greater water efficiencies, namely the genetic aspect of different grape vine plants and their variances in water-stress tolerance. Only one study comparing the magnitude of agronomic/practical and genetic efforts was found (Medrano et al., 2015), thus more research on the importance of technical and agronomic practices vs. genetic approaches towards reducing water use would be of interest, to indicate which of the two branches hold the largest potential in reducing overall water use, so that industry efforts can be adjusted accordingly.

6.4 Final reflections

Sustainable water use is of high concern for actors within the wine industry, which is also reflected in the content of wine sustainability programs and the growing amount of sustainability initiatives within the industry. Many sustainability schemes have already adopted an impressive amount of means for reducing the negative environmental impacts associated

with wine production, including water management. Yet, as have been recognized by both practitioners and academia, there is great need for improved water use efficiencies (Medrano et al., 2015; Costa et al., 2016; Christ & Burritt, 2013). While this study has looked into efforts for improving water management within sustainability programs from a managerial perspective, it might be appropriate to zoom out and put the study as a whole into greater context.

A main issue that the wine industry appears to be facing is the lack of a standardized way of estimating water use in connection to wine production. This is deemed important to correct for as it obscures meaningful insights into water use within the industry - something that may be problematic both for internal and external stakeholders. As suggested above, a framework allowing for a fair comparison, taking varying climatic conditions and other relevant factors into account appears apt. Suggestively, international industry branch organization such as FIVS and the OIV should agree on such a standardized method and help ensure implementation and use of such a framework for water use estimations. As sustainability programs appear to make a clear distinction between vineyard and winery operations, separate, detailed standards for water use estimations in these areas may be helpful. With detailed water use quantifications in different processes and operations, efforts for water reductions could be designed accordingly. Generally speaking, quantitative, or measurable, indicators are necessary to set meaningful goals and targets and to evaluate performance against (e.g. Braam, 2010; Mainz, 2003) and would lay ground for any future water use estimations, thus a greater adoption of quantitative indicators are strongly encouraged.

Taking a step back from the information collected throughout this research and looking at the core question of this study, it appears that the answer boils down to appropriate adaption of management efforts and program design according to individual and regional needs, using a good mix of technical, human and financial resources. Level of education and the human factor appear to be especially central determinants in the quest for improved adoption of sustainable management of water resources.

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Appendix A: Examples of requirements from assessment criteria (SWP, USA)

5-4 Irrigation System			*Vineyard*
Category 4	**Category 3**	**Category 2**	**Category 1**
An engineered* micro-irrigation system (including drip irrigation or micro sprinklers) was installed in the vineyard.	A low-flow engineered* sprinkler irrigation system was installed in the vineyard.	A high-flow engineered* sprinkler irrigation system was installed as the only method of irrigation in the vineyard.	A non-engineered or flood irrigation system was present in the vineyard. *(Select N/A if the site was dry farmed during the assessment year)*
*A well-engineered irrigation system consists of components such as flow meters, back-flow prevention devices, flow controls, flush valves, and filtration and injection equipment. The system should have energy efficient features to accommodate for site variation and may have engineered pressure compensation devices where needed.			

Figure IV: Excerpt from criteria on Irrigation Systems from Chapter 5 of the Workbook, Vineyard Water Management. Source: California Sustainable Winegrowing Alliance, Wine Institute, and California Association of Winegrape Growers. (2012). California Code of Sustainable Winegrowing Workbook (3rd ed).

Appendix B: Interview guide

[Short introduction]
I am studying Environmental Management & Policy at Lund University, Sweden. I am currently underway doing my MSc thesis in where I am looking into the topic of water management in the vitivinicultural industry. More specifically I intend to compare the program design and performance of different sustainability programs around the world (Australia (SA), Chile, Portugal, South Africa & USA (CA)) in order to identify ways to better improve uptake of water saving practices among wine producers. The intention with my research is to gain a better understanding into how different vitivinicultural sustainability programs in water stressed regions are working towards greater adoption of sustainable water management practices among members and how they are following up on implementation, in order to gain better insight into why some programs are more "successful" than others. This information would consequently be used to identify ways of better uptake of water saving practices among wine producers around the world. To be more clear, my overarching RQ to my thesis is: '*How can vitivinicultural sustainability programs improve adoption of sustainable management of water resources among their members?'*.

Questions for interviewees:

- Understanding areas of responsibility: Do you hold insights/access to documents on performance among members in terms of water management?
- (If not available online): Would you be willing to share the assessment criteria for the water management "chapter" of the program Workbook with me?
- Management of information: How are (managers of) the sustainability program following up on implementation of recommended/required water saving practices among members?
    - Is the performance of the program and individual producers evaluated in any way?
- Apart from the resources available online - do you provide any other material/support for your members (e.g. through educational events, work shops etc.) in order for them to improve their management of water on the vineyards and in the wineries?
    - If yes, how often do these educational events take place and how (online, in-person)? And, would you be able to share this kind of education material (e.g. PP slides or similar) with me?
- What is the overall performance among members in terms of water management, i.e. data on water footprints (preferably reported in L consumed water /L produced wine), or % of total score from external/internal audits etc. Has performance improved over time?
- On what resources are the required/recommended water management practices in the different programs/assessment schemes based on? (Research? Inspiration from other sustainability programs? etc.)
- From where is information on what is considered best practice of water management in the vineyards and the wineries obtained?
- Are the selected programs sharing best practices with other sustainability programs in any way? (e.g. FIVS or other forums). If not, why?
- What do you consider to be key barriers and drivers for improved adoption of sustainable water management by members within the scope of this sustainability program?

Appendix C: Reported member performance, WASP, Portugal

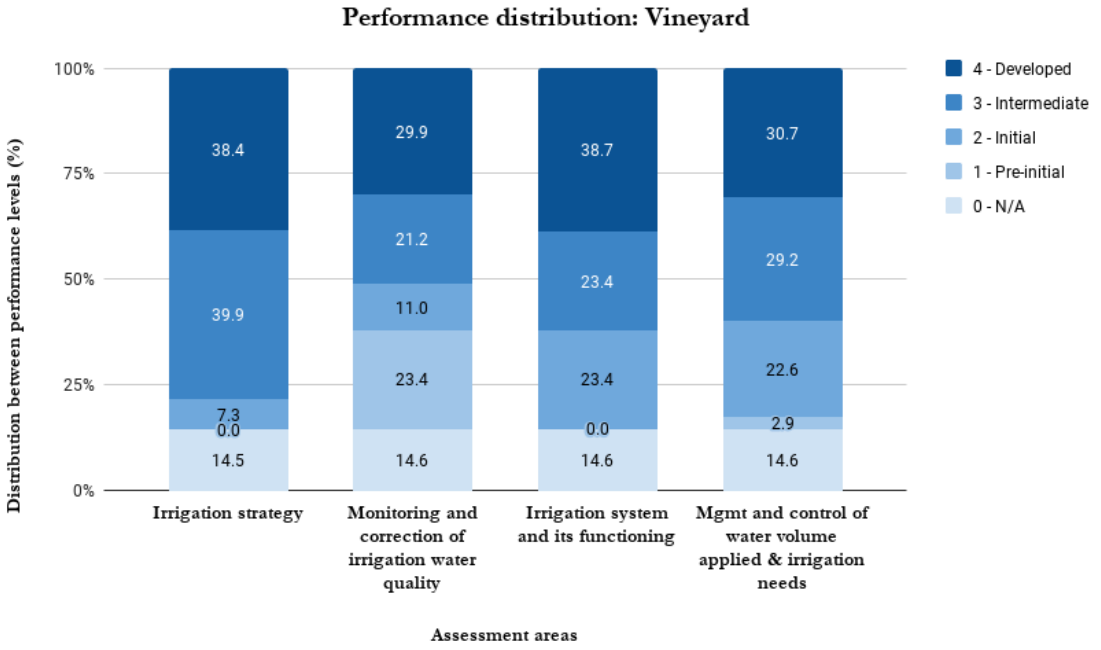

Figure C-1: Performance distribution among WASP members - vineyard

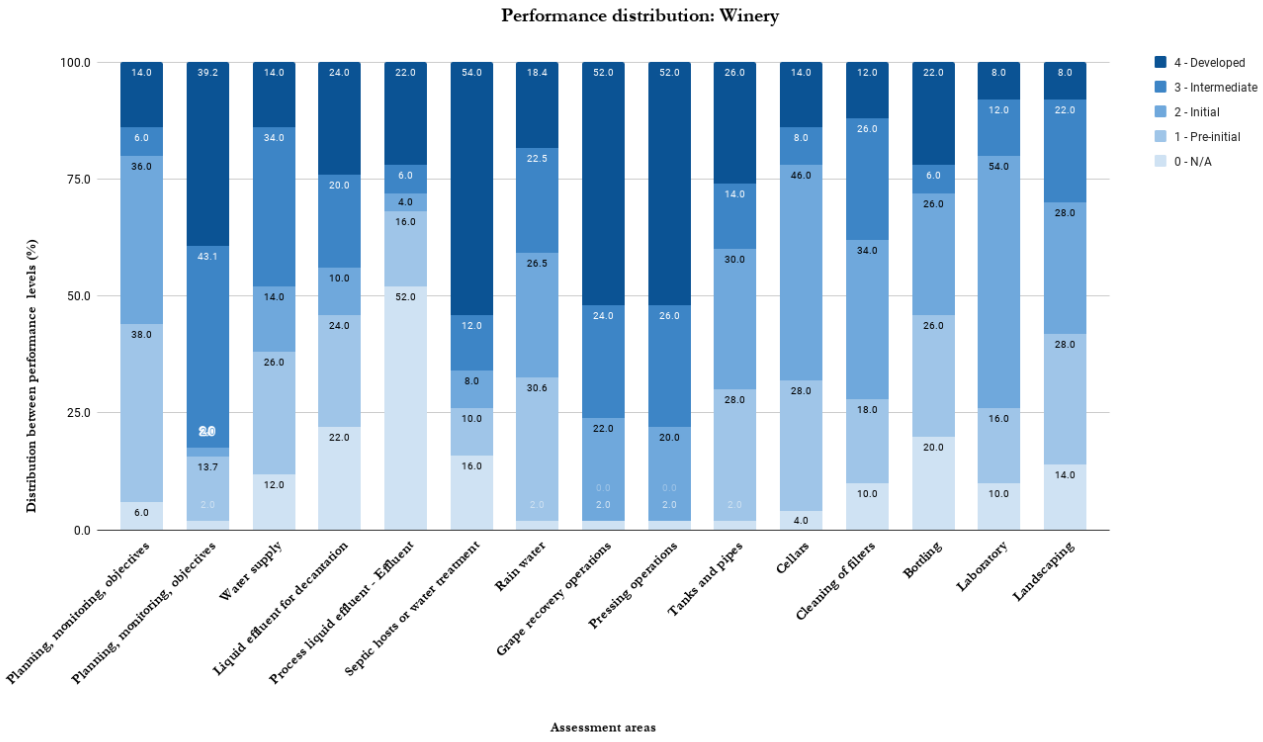

Figure C-2: Performance distribution among CSWA members - winery

Appendix D: Reported member performance, SWP, USA

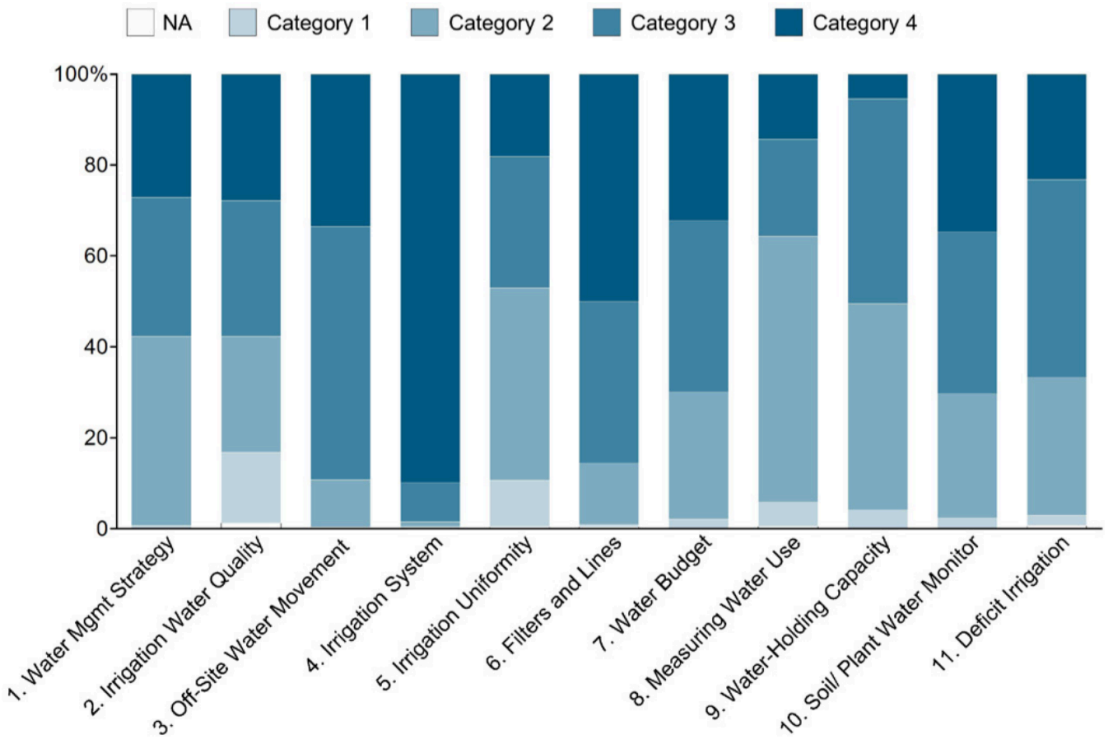

Figure D-1: Performance distribution among SWP members - vineyard

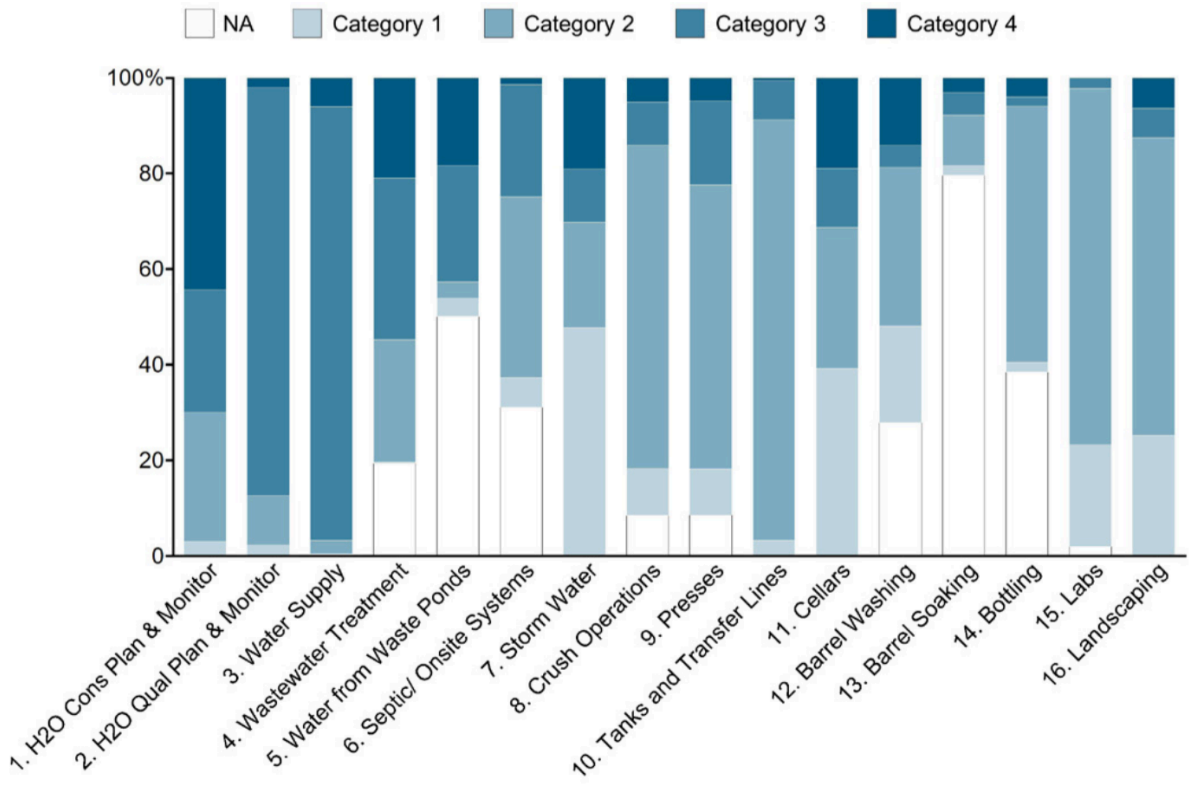

Figure D-2: Performance distribution among SWP members - winery