Water Management Policies and their Impact on Irrigated Crop Production in the Murray-Darling Basin, Australia

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Am Neuen Palais 10, 14469 Potsdam
Tel.:+49 (0)331 977 2533/ Fax: 2292
E-Mail: verlag@uni-potsdam.de

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To My Family

Abstract

In general, water management policies encompass a variety of social, economic and environmental issues, and have either a direct or indirect impact depending on the aim or the strategy of the policy.

In cases of water market failures, governmental intervention might be the solution to ensure sustainable water usage, however all the costs and benefits must be considered in order to improve the initial situation. Water management policies in the Murray-Darling Basin, Australia specifically impact the agricultural industry and since this is the primary water user, they are of the utmost importance.

In this region, especially during periods of drought, available water was not only severely over-used but also in high demand. In the past, these concerns were not properly addressed by the policies implemented by the State governments as the study finds with the help of explorative expert interviews.

In this thesis, an economic impact analysis shows that irrigation farming is particularly susceptible when applying certain water management policies.

By comparing different pricing and non-pricing water management policies with the help of the WatIM-Model, it is found that the impact is most severe on water intensive crops that are less water productive. This is most evident when applying mandatory non-pricing water management policies since production and profit losses are the highest.

Moreover, in cases of higher water prices and lower water availability, water is re-allocated from less water productive to higher water productive crops.

A combination of droughts and water demand decreasing policies, in the same region, will create a situation whereby highly water dependent crops that are less water productive, cannot be cultivated.

Water usage conflicts invariably occur, between different water users including the environment. Changes in policy strategies, in the Murray-Darling Basin, now favour the environment and this has and will have a detrimental effect on the agricultural industry in particular.

However, if the observed policies are able to solve the problems of water market failures, governmental failures, and over-consumption of water, the economy will adapt and ultimately benefit.

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List of Abbreviations

AARES	Australian Agricultural and Resource Economics Society
ABARE	Australian Bureau of Agricultural and Resource Economics
ABARES	Australian Bureau of Agricultural and Resource Economics and Sciences
ABS	Australian Bureau of Statistics
ACCC	Australian Competition and Consumer Commission
ACT	Australian Capital Territory
AU$	Australian Dollar
BRS	Bureau of Rural Sciences
CDL	Current diversion limit
CSIRO	The Commonwealth Scientific and Industrial Research Organisation
CSO	Community service obligation
DAFF	Australian Government Department of Agriculture, Fisheries and Forestry
e.g.	Exempli gratia (Latin, meaning: for example)
et al.	Et alii (Latin, meaning: and others)
etc.	Et cetera (Latin, meaning: and other things)
f., ff.	Folio (Latin, meaning: on the next page(s))
FAO	Food and Agricultural Organization of the United Nations
FAOSTAT	FAO Statistics Division

GL	Gigalitre
GVA	Gross value added
GVIAP	Gross value of irrigated agriculture production
ibid.	Ibidem (Latin, meaning: the same place)
IIAWM	Integrated Irrigated Agriculture Water Model
Incl.	Including/ inclusive
IPART	Independent Pricing and Regulatory Tribunal
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
ML	Megalitre
NA	Not available
OLS	Ordinary-Least-Squares
R&D	Research and development
RtB	Restoring the Balance
SA	South Australia
SDL	Sustainable diversion limit
SMDB	Southern Murray-Darling Basin
t	Tonnes
TSLS	Two-Stage-Least-Squares
VIC	Victoria
WatIM	Water Integrated Market
WMP	Water management policy

Volumes of Water

Volumes of water used in this thesis are expressed as either megalitres (ML) or gigalitres (GL) which is the typical unit used in statistics and the literature in Australia.

One thousand litres	1,000 litres =	1 kilolitre	1 KL
One million litres	1,000,000 litres =	1 megalitre	1 ML
One billion litres	1,000,000,000 litres =	1 gigalitre	1 GL

Volumetric data is used with the biggest possible measuring unit since bulk water resources are used for irrigation issues. Water prices are – according to common Australian practise – announced in Australian Dollar per megalitre (AU$/ML).

1 Introduction

In her poem *My country* by Dorothea Mackellar, a well-known Australian poet, written in 1907, she described Australia as "a sunburnt country, a land of sweeping plains, of ragged mountain ranges, of droughts and flooding rains." (Mackellar, 2011).

Australia is no stranger to these extreme weather conditions that create hardships and challenges. This is particularly true in areas where fresh water is a vital resource not only for man and beast but for the environment as a whole.

However, while water is a life necessity, its vulnerability forces man to manage and use it properly, not only in the short-term but in the long-term, so that future generations will not be deprived of this precious resource.

One of the greatest challenges facing the Australian government and the water users is the enormous fluctuations in water availability caused by the recurring droughts and floods. Droughts are periods usually lasting three to four years with particularly low annual rainfall, however from 2001 to 2009, an especially long-lasting drought affected the south-eastern part of Australia. While water is hardly considered infinite, even under "normal" weather conditions that can often result in rivalries, the occurrence of droughts only exacerbates and intensifies this scarcity related problem. (Dinar, 2001, p. 285).

To solve this problem and to handle droughts in Australia, the management of water is of critical importance.

Water management is the planning and allocating of water by either water markets or by regulations. When markets cannot solve these user conflicts, due to market failures, institutional interventions may be deemed necessary to prevent over-usage of water and environmental damages.

Despite several water reforms that introduced water management policies to handle water scarcity, it seems to some that the cultivation of water intensive crops, such as rice and cotton, are out of place in a country facing water scarcities.

In Australia, approximately 60 % of total water usage is consumed by the agricultural industry (Australian Bureau of Statistics, 2013a, Table 1), which is by far the largest water user.

This thesis focuses on a number of different aspects: water market regulations examined from a theoretical and practical perspective, the over-consumption of water, the existing and potential institutional arrangements addressing this matter, and the analysis of the water management policies in the Murray-Darling Basin, including the impact they have on irrigated agricultural production, and water consumption.

The scope of this research centres on the water management policies pertaining to periods of drought, with the particular attention paid on decreases in water demand rather than increases in water supply.

To achieve this objective, four water management policies are examined and analysed. These include two non-pricing strategies (the water sharing plan and the "Restoring the Balance" (RtB) program), and two pricing strategies (the subsidy removing and the environment compensating irrigation tax).

Finally a new model, the Water Integrated Market (WatIM) Model was developed by the author to assess the aforementioned water management policies and the impact they have.

For the purposes of this thesis, water consumption and water use are one and the same.

In the following subsections, studies involving the very same water management policies are outlined; identifying research gaps that the author feels exist. These gaps formed the basis of the three research questions. The thesis overview and the applied research design are also explained below.

1.1 Recent Studies Review

State interventions in water markets invariably have economic, social, and environmental effects. For this reason, whenever water management policies are introduced, their effectiveness and costs must be carefully studied. Many scientists and governmental organisations in Australia have addressed this issue as it relates to the Murray-Darling Basin (MDB). The following overview of previous studies focused on the policies of the Basin Plan, the RtB program and water pricing.

Studies addressing the Basin Plan

The following relevant studies commissioned by the Murray-Darling Basin Authority (MDBA) were gathered to illuminate the "black box of knowledge" regarding the potential impact the Basin Plan would have in the MDB.

The Australian Bureau of Statistics (ABS) and the Australian Bureau of Agricultural and Resource Economics and Science (ABARE-BRS) (2009) provided data that was meant to enable the MDBA to assess the economic and social impacts of the Basin Plan on a sectoral, regional, and local level. Their report suggested how to proceed in the Basin Plan development and which methods and assessments would help to estimate potential impacts. (Australian Bureau of Agricultural and Resource Economics, Bureau of Rural Sciences and Australian Bureau of Statistics, 2009; Murray-Darling Basin Authority, 2011c, p. 10 ff.)[1].

Frontier Economics stated that government involvement by the implementation of the Basin Plan could result in a structural change; however this could be deemed desirable if it improved productivity and promoted innovation. Further they found that the impact on farmers across the Basin could be both variable and unpredictable since the "benefits and costs of change can be unevenly distributed." (Murray-Darling Basin Authority, 2011c, p. 18; Frontier Economics, 2010, p. v). Furthermore, an economic benefit-cost-analysis was applied to compare benefits to the environment from higher water allocations than previously issued and the economic costs which derive from reducing irrigation

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[1] In this thesis direct quotes are made recognisable with quotation marks "…" and indirect quotes without quotation marks. If the source is located within one sentence and in front of the full stop, the source refers to that sentence. If the source is located behind a sentence/full stop, the source refers to several sentences before or the whole paragraph.

water availability by the implementation of the new sustainable diversion limits (SDLs) (Murray-Darling Basin Authority, 2011c, p. 3 and 22 ff.; Frontier Economics, 2011, p. 2).

Other studies had the goal to quantify social and economic benefits of the Basin Plan. Morrison, M. and MacDonald, H.D. (2010) for instance estimated non-use values for five environmental attributes by applying the qualitative approach of inquiries in their study (Murray-Darling Basin Authority, 2011c, p. 3 and 25 ff.; Morrison and MacDonald, 2010).

The Centre for International Economics (2011) found that the benefits might be greater than the costs when non-use values are considered (Centre for International Economics, 2011, p. 28 f.; Murray-Darling Basin Authority, 2011c, p. 4 and 31 ff.).

Crossman, N. et al. (2011) from CSIRO concentrated on an analysis of benefits to the environment by the Basin Plan by applying a hydrologic modeling approach, an environmental evaluation and a benefit-cost-analysis (Crossman et al., 2011; Murray-Darling Basin Authority, 2011c, p. 4 ff.).

ABARE-BRS developed the ABARE-BRS Water Trade Model, an economic model analysis based on several diversions reduction scenarios, to analyse the economic impact induced by the Basin Plan (Hafi et al., 2009).

Mallawaarachchi, T., D. and Adamson, D. et al. from the School of Economics, Queensland University, Australia developed a regional, contingent optimisation model, which was used to apply an economic scenario analysis concerning the regional impact of the Basin Plan (see Subsection 5.1.7.2.1) (Adamson et al., 2011, p. i and 20 ff.; Murray-Darling Basin Authority, 2011c, p. 5 and 62 ff.).

The Integrated Irrigated Agriculture Water Model (IIAWM) which is a hydrologic and economic model developed by the Centre for Water Economics, Environment and Policy at the Australian National University is able to predict employment-changes as a result of the introduction of the Basin Plan (Jiang, 2010).

Another economic model analysis was prepared by Wittwer, G. from the Monash University, Australia by applying the TERM H2O model. He focused on the analysis of short-, and long-term macroeconomic impacts induced by the Basin Plan. (Wittwer, 2011; Murray-Darling Basin Authority, 2011c, p. 6 and 72 ff.).

Besides those economic analyses, studies were conducted to observe community and local impacts by analysing census and other socio-economic data. To name some of those studies, ABARES measured potential community vulnerability to changes in water availability according to the *Guide to the proposed Basin Plan*. The report from Arche Consulting (2011) provided results from several case studies for selected local government areas (Murray-Darling Basin Authority, 2011c, p. 8 and 132 ff.).

Marsden Jacob Associates, RMCG, Environment & Behaviour Consultants, DBM Consultants, the Australian National University, G. McLeod, G. Roth, D. Cornish and T. Cummins considered the local community impact in their studies (Murray-Darling Basin Authority, 2011c, p. 7).

Studies addressing the RtB program

Several qualitative and quantitative studies were concerned with social and economic impacts of the RtB program in the MDB.

Marsden Jacob Associates (2012) conducted an irrigator survey to analyse the impact of the RtB program on individual farmers who sold water access entitlements to the government (Marsden Jacob Associates, 2012).

Hyder Consulting applied stakeholder consultations and telephone interviews to examine the impact of governmental water access entitlement purchases (Hyder Consulting, 2008).

The motives and willingness of farmers to sell water to the government were observed by Wheeler et al. (2012) by applying an irrigation farmer survey (Wheeler et al., 2012).

Economic analysis was conducted by the Australian Bureau of Agricultural and Resource Economics (ABARE)[2]. The static Water Trade Model was applied to study the impact of the RtB program on the value of output of irrigated agricul-

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[2] The Australian Bureau of Agricultural and Resource Economics (*ABARE*) and the Bureau of Rural Sciences (*BRS*) merged to the Australian Bureau of Agricultural and Resource Economics and Sciences (ABARE-BRS or also called *ABARES)* in July 2010.

tural production, on water consumption and land use in different regions of the MDB (Hone et al., 2010, p. 1).

Dixon et al. (2012) from the Monash University, Australia used the multi-regional national dynamic CGE model TERM-H2O to discover the potential economic impact of the RtB program for the period 2009 – 16 (Dixon et al., 2012, p. 99 ff.).

Adamson et al. (2011) used the state-contingent model of risk and uncertainty to estimate economic consequences of the RtB program by specifying water resources and water rights (Adamson et al., 2011).

Studies addressing water pricing

Franco-Dixon et al. (2007) analysed the financial impact of different water price levels on farms in the Emerald Irrigation Area. They applied a linear programming model and found with the help of water pricing scenarios that water demand barely responded to price changes since the initial water price was so low that it had nearly no effect on demand. Greater impacts on quantity of demanded water have the climate change, weather extremes (drought and floods) and changes of agricultural policies or product prices. (Franco-Dixon et al., 2007).

Research gap

While all of these studies addressed an impact analysis of water management policies (WMPs), they can only be considered meaningful once the reasons for misbalances and over-usage of water are clarified. Additionally, one must question whether or not market regulation (would) indeed improve the initial situation. None of the studies noted above asked the question of reasonability of governmental intervention before starting or while observing the impact of WMPs.

There are two reasons that might trigger market interventions and water reforms: either the water market fails or there is a governmental failure that makes it necessary to correct water management practises. Therefore, it is important to identify the reasons for these misbalances in the water market and the environmental damages that might be triggered by intensive water consumption.

This study does not only analyse the impact of WMPs on agricultural crop production, it also examines water market characteristics and highlights reasons why governments often intervene in water markets. This is done first on a theoretical basis and then applied to the case study region of the MDB.

Furthermore, the above listed studies mainly focused on the analysis of a single WMP[3] and did not include alternative WMPs on a Basin scale[4].

When the goal is to provide the best solution for a problem, results gained from an impact analysis should be weighed against other opportunities. Governments can use a wide range of policy instruments to intervene markets. They may choose to support and strengthen the market mechanism or they may choose to replace them. It is essential to examine the possible impact of several instruments (impact-comparing approach) to find the best solution for an existing problem, balancing economic costs and the benefits for the environment against the desire to keep or make water bodies healthy.

To provide an impact-comparing approach, it is important to use the same methodology and (model) framework for all observed alternatives. In this way, contortions due to different approaches, basis data and limitations do not occur. For this study such a tool was developed: the WatIM-Model is used to simulate different WMPs and their impact on irrigated agricultural crop production in the MDB.

In the following sections, the research questions are formulated and the structure of the thesis is clarified. Subsequently, the applied research design is presented.

1.2 Research Questions and Thesis Overview

The objective of this research is to determine the reasons for the water problems in the MDB and what impact different WMPs have on irrigated agricultural crop

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[3] Even if the same model is used to analyse different WMPs in separate studies, results of the studies were not compared with each other.

[4] With two exceptions: Local case studies, which consider alternative WMPs were conducted by Arche Consulting. ABARE-BRS estimated the combined impact of RtB program, infrastructure investment program and the Basin Plan (ABARE-BRS, 2010, p. 13). Those three WMP have more or less the same goal (and are therefore complementarities): to quantitatively reduce water consumption by either reducing the available amount of water rights on the market or by defining limits of water extraction (caps).

production, and what changes may occur when applying one or the other WMP in the MDB.

The purpose of this thesis is to answer the following questions:

1. Why are water markets regulated?
2. What caused the over-consumption of water in the past and how are the existing and potential institutional arrangements addressing this problem in the MDB?
3. What economic effects might the WMPs have on irrigated crop production in the MDB?

To address the first research question, the main characteristics of the resource water and its markets are outlined in Chapter 2. Furthermore, cases of water market failures are covered theoretically and the regulation theory is used to understand reasons for state interferences. Those findings are the basis for the examination of the regional water market in the MDB, Australia.

To be able to answer the second research question about the reasons for the market failures in the MDB, Chapter 3 begins by giving an overview of the rural irrigation practises and weather conditions in the MDB to help to understand what caused the over-consumption. Then, rural water markets with its infrastructural characteristics involving institutions and market agents are explained. Later, the reader is introduced to the water right trading scheme with particular attention paid to water right trading market characteristics and mechanisms. When the functioning of the water market in the MDB is understood, reasons for over-consumption of water can then be detected. The second part of this research question regarding existing and potential institutional arrangements is treated in Chapter 4. This includes the two potential pricing and two non-pricing WMPs, which were and are intended to be implemented in the MDB.

The first non-pricing policy examined discusses the water sharing plans that regulate the allocation of water between competing water users and defines the maximum water extraction levels to prevent over-consumption. Particular attention is given to the upcoming Basin Plan, which is a water sharing plan for the entire MDB region. The second non-pricing policy strategy discussed in this thesis is based on the existence of water right trades. The Australian government participates in the water right trading market and buys water access entitlement from willing farmers to restore the balance in the MDB. This so-called RtB program is clarified in Subsection 4.2.

In addition to the two non-monetary WMPs, two potential water pricing strategies for the MDB, namely the subsidy removing and a taxation strategy are observed. However, both are not considered by policy makers and may not be implemented in the MDB.

The third research question is addressed in Chapter 5 by applying an economic impact analysis. Using a partial equilibrium model, which has been developed by the author, the above mentioned four WMPs are separately analysed in the various scenarios to determine the different impacts they have on irrigated agricultural crop production and water consumption (Chapter 5.1). The results of these scenarios are compared to highlight the effects they have on irrigation crop industry. By observing differences of water consumption, output and profit changes in wet and dry years, it is possible to determine, which WMP is the most sustainable and has the least negative impacts on the irrigation crop industry.

The following subsection describes the research design and the methods used to answer these research questions.

1.3 Research Design

In order to understand the objectives of science, it is important to reflect and understand reality. But what is reality?

One of the problems faced in defining reality is that our own individual perceptions vary. Therefore, reality can be described as a world of "complex, dynamic flow of unique and [sometimes] unrepeatable phenomena and events [… that might not even be] directly observable." (Jaccard and Jacoby, 2010, p. 9 ff.). Despite the complexity of our world, science attempts to untangle and understand reality by formulating research questions and hypotheses that can often be answered and validated by applying research methods.

Originally a quantitative research method was chosen to answer the research questions of this study. Using the quantitative mathematical modeling approach, a multi-market Cobb-Douglas model was developed. However, exact and useful data was not available, which leads to insensitivity of the model. Furthermore, it showed fundamental inaccuracies of reasoning. Therefore, the author decided to reject this mono method (see Appendix 7.3) and change to a different research approach.

In the past, mono method studies used the qualitative and quantitative approaches separately. However since the 1990s', a new research approach called the *mixed method approach* that combines both methods has been used. Many researchers[5] now attach the same level of importance to this new method as they do to the mono method approaches (Bergman, 2011, p. 271).

However, since this is a relatively new approach, the scientific community is still divided as to its relevance and definition with disagreements regarding "its philosophy, approaches to design, methodology and approaches to analysis" (Gray, 2009, p. 203). There is even a lack of consensus regarding the nomenclature to be used with many opting to use terms such as multi-methodological approach, mixed model studies, mixed methods research, and the integration of qualitative and quantitative approaches instead of the term mixed method approach. Despite concerns about the combinability of the qualitative and quantitative research methods, both were successfully mixed in empirical studies. (Kelle, 2008, p. 46 f.).

The main advantage of using the mixed method approach is that any weaknesses resulting from the use of one approach can be compensated by the strengths of the other (ibid.). Recently, the mixed method approach has experienced a remarkable rise in popularity, not only in social, behavioural, and political (related) sciences (Bergman, 2009, p. 1; Harrits, 2011, p. 150) but also in organisational and management research, the health sector and psychiatry (Morse and Niehaus, 2009, p. 15). This confirms the applicability and successfulness of this approach.

The new approach for this thesis is a mixture of qualitative and quantitative research methods. The goal is to create a basis for an analysis, which is as holistic as possible regarding sustainable water management policies and their impact

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[5] To name some of them: Alan Bryman, Vicki L. Plano Clark, John W. Creswell, Abbas Tashakkori.

on irrigated crop production in the MDB. In order to understand and reconstruct complex and dynamic reality, the author has adopted a mixed research method that utilises the advantages of both approaches to gain multiple views on the research issue.

For this thesis the methodological framework of *exploratory design* was chosen in which two phases of research are applied. The first methodological phase is characterised by applying the qualitative research method to generate data. After collecting and analysing this data, the derived findings are used as input for the second, the quantitative phase. (Creswell et al., 2009, p. 67 ff.). The exploratory design is often used to develop a new instrument (Creswell, 2009, p. 211 f.), which has been done in this thesis. It helps to include data (e. g. informal information) gained from qualitative research. This information may not be available while just focusing on quantitative methods since some relevant information is not quantifiable and would be excluded from consideration when not applying both methods.

As a basis for the first phase of the exploratory approach, an extensive literature review was made to pursue two objectives. The first aim was to gain theoretical background knowledge about characteristics of water and its markets. The second objective was to get an overview about the situation of Australian water resources and markets, the irrigated agricultural crop production in the MDB, and the institutional and legal framework in this region.

On the basis of this literature review, the qualitative method of expert interviews was used and is described in Subsection 1.1. Both, the literature review and findings from interviews have been used to answer the first two research questions. After collecting and analysing data from the expert interviews, the second phase was introduced by applying the quantitative research method of economic modeling (see Subsection 1.3.2). For this quantitative research phase, input data from the first phase of expert interviews and from Australian and global statistics[6] were used. By applying simulations with the linear WatIM-Model, output data was generated, analysed and finally interpreted. This method was used to answer the third research question.

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[6] For the most part, economics uses statistical data that was derived from the routine social research of statistical bureaus. Frequently, those bureaus use random samples by applying various survey instruments. (Diekmann, 2011, p. 21).

In the following, the applied qualitative and quantitative research approaches are explained separately.

1.3.1 Qualitative Approach

Qualitative research points out the social perspective of reality by explaining the meaning of the processes and social experiences through the application of descriptive or narrative techniques (Bergman, 2009, p. 11).

The main difference between qualitative and quantitative research approaches is the type of data used. Qualitative research uses non-numerical, verbal data (e. g. interview texts, observation records, and objects such as photos, paintings) by describing and understanding correlating effects. In contrary, quantitative research uses measurable data that explains inter-related facts. (Bortz and Döring, 2006, p. 296 ff.).

The goal of the first phase of this study is to discover new aspects that were not known to the author. Using the literature review and experiences from the Cobb Douglas model, the author's goal was to derive an overview of several areas. These included the status quo and potential developments of the water market, irrigated crop production, potential for technological change in the irrigating sector, and future perspectives in the MDB regarding climate change and adaptive capacities. Furthermore, it was of interest to obtain individual assessments and meanings from experts and to be able to compare statements of agent groups to the same issues. With this approach, important interest conflicts could be explored and included in the research. The author also tried to find reasons for the insensitivity of the Cobb-Douglas model and to gain new insights regarding the development of a regional market model that would better reflect reality and help to answer the third research question.

By using the qualitative approach of expert interviews, these discoveries were made. (Meuser and Nagel, 1991, p. 441). Expert interviews are mainly used to generate a foundation of knowledge and a first orientation and overview over a very complex and difficult field of research. They are applied to increase the awareness of the researcher about potential or existing problems, not to collect data that is comparable, complete, and can be standardised. (Bogner and Menz, 2009, p. 64). Expert interviews are often used in mixed method research studies but can be also applied as a separate technique. (Meuser and Nagel, 1991, p. 441 f.).

But what is the definition of an expert? In general terms, they are people who have specific knowledge that they either transmit on request or apply to solve a specific problem. They are witnesses of the processes that are relevant to the researcher. (Gläser and Laudel, 2010a, p. 11 f.). In comparison to other forms of open interviews, expert interviews differ because the context in which the expert is involved is an organisational and institutional one. The position of the expert, within an organisation or institution enables him or her to provide additional information such as eyewitness reports and information regarding institutional and organisational background. This information is only available by interviewing experts. (Meuser and Nagel, 1991, p. 442 ff.). This enables the researcher to receive exclusive and new information.

Bogner and Menz (2009) were particularly interested in the term "experts" in the methodological context. They divided experts into three groups: voluntaristic, constructivistic, and cognitive-sociological.

According to Bogner and Menz, *voluntaristic experts* are people who possess the abilities, skills and information to manage their everyday lives. This is of great benefit to scientists. (Bogner and Menz, 2009, p. 67 f.).

The *constructivistic expert* group is differentiated between the methodical relational approach and the social representative approach. Both approaches have a referential connection with each other. A constructivistic expert in the sense of the methodical relational approach is an expert who is to a certain extent the "construct" of the research interest itself. In these cases, the scientist is interviewing people who have important positions in an institution or company or have an academic title, which provides specific knowledge. The social representative approach defines a person who is clarified by society to be an expert. Hence, persons who are seen as experts are of specific research interest to the scientist and at the same time representatives of the society. (ibid., p. 68 f.).

The *cognitive-sociological expert* possesses specific knowledge that has been gained from his or her profession, whereas a specialised amateur has gained his or her knowledge during leisure time activities (Bogner and Menz, 2009, p. 69).

While generally speaking one can group most experts into these three categories, it is sometimes difficult to distinguish between certain groups, especially between professional and private knowledge experts. Bogner and Menz (2009) proposed that rather than categorise experts into three groups it is preferable to classify them by their specific knowledge. They further defined these knowledge dimensions as:

1. Dimension of technical knowledge: expresses specialised knowledge about manufacturability and availability, processes and operations, special applications or bureaucratic competences etc.
2. Dimension of process expertise: embodies insights and information about the course of action, interactional routines, and organisational constellations.
3. Dimension of interpretive knowledge: accrues as a result of the scientists' systematisation and abstraction of collected information. The knowledge of experts is identified as interpretive knowledge after data is collected and analysed by the scientist.

(Bogner and Menz, 2009, p. 70 f.).

In contrast to quantitative approaches, qualitative approaches work with a much lower number of analysed cases. The amount of data depends on the goal of the research. When the goal is to discover new scientific knowledge, the number of cases is less relevant than in cases where the aim is to validate statements of theory[7]. Discovering new scientific knowledge can often be accomplished by one interview. (Brüsemeister, 2008, p. 19).

For this study, 18 explorative expert interviews (see Appendix 7.1 for classification of experts and expert knowledge according to Bogner and Menz) were conducted. The intention of applying this approach was to get a first orientation about the topic and an overview about the complexity of water related issues in rural Australia and the MDB. Additionally, the goal of this qualitative approach was to create greater awareness of the problems that occur with the implementation of WMPs and its possible impacts on crop production and other interest groups. Semi-structured guided, explorative interviews helped to thematically structure the exploration. These interviews were conducted in a three-week pe-

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[7] To validate statements of theory, a significant measurable quantity is decisive in order to verify or refute the observed hypothesis, which is relevant in quantitative approaches.

riod in February 2011 in Melbourne and Canberra, Australia. The interviewees consisted of ten scientists, three farmers' representatives, two policy makers, two farmers, and one indigenous person.

Procedure

Preparation of the semi-structured interview

In preparation for these non-standardised, semi-structured interviews, the author developed a list of issues and questions. In some cases, different questions were formulated to compensate for the varying backgrounds of the experts. The following issues were included in the guideline:

- Water market in the MDB
- Water right trade in the MDB
- Water prices
- Irrigation in the future
- Technological potential of agricultural industry
- Adaption to climate change
- Restoring the Balance (RtB)/buyback program
- Metering/groundwater use
- Economic modeling

Since the order of these issues was not necessarily relevant, this allowed the author to adapt the sequence of questions to create a more relaxed environment. This provided a greater insight into the subjective meanings of the various concepts and events as well as inside-information from the interviewees. (Gray, 2009, p. 373).

The selection of experts

In order to get a more holistic overview regarding the rural water issues in the MDB, most involved groups of market agents are included in the study[8]. This enables the researcher to include diverse interests and views of agents in the

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[8] Not all water market agents were involved. For instance, representatives of water supplying processes were not interviewed.

study. Expert groups were separated into scientists, farmers' representatives, policy makers, farmers, and indigenous people.

The quality of the information gathered during these interviews is obviously dependent on the interviewees (Gläser and Laudel, 2010b, p. 117). By focusing on voluntaristic, constructivistic and cognitive-sociological experts, problems such as the uncertainties relating to the state of knowledge of the interviewee with regard to precise information were greatly reduced.

In preparation for the interviews, the author contacted all of the experts first by e-mail. This initial correspondence not only introduced the author but also explained the field of research, the aim of her study and a request to conduct a personal interview while she was visiting Australia. In response to these e-mails, most experts agreed to participate in research and appointment dates were set.

Since the duration of the stay in Australia was limited to three weeks, it was important to arrange as many interviews as possible within this short period of time. Fortunately, this visit coincided with the 55th AARES conference in Melbourne. This allowed the author to schedule a series of interviews, with attendees from other cities, both during and immediately after the three-day conference thereby eliminating the need to add additional travel to her existing schedule. A series of interviews were also conducted in Canberra where many governmental institutions such as ABARES, ABS and the Parliament of Australia are located. This provided an additional opportunity to meet several experts for interviews.

In the case of the aboriginal woman and the two farmers, the author did not contact them beforehand but met them during her stay in Australia.

Conducting expert interviews

The interview started with the author welcoming each interviewee and showing her appreciation for their willingness to do the interview. The author then reiterated what she had already included in her initial e-mail. By making the research goals and the reasons for the interview transparent, it was possible to create a more trustful and comfortable environment. Each interviewee was also assured that their participation in the research project would remain anonymous. Finally, the author asked each interviewee for his or her permission to make an audio recording of the session. This would not only allow the author to make a transcript of the interview but also to refer to it and use it for future study. After the interviewee gave his or her permission, the interview started.

In cases where more than one interviewee from the same organisation or institution attended the interview, attendances were summarised to one interview-group (see Appendix 7.1; for instance expert codes S6a, S6b, S6c). This was done to differentiate the voices of the interviewees and make it easier to transcribe what was being said especially when there were multiple speakers.

Every attempt was made to make the questions clear and concise. By adopting the semi-structured guided interview format, queries and interposed questions were possible. The goal of the author was to guide the interviewee to the object of interest so as to gleam as much expertise as possible. (Mayer, 2008, p. 37 f.). In addition to the audio recording, the author also took notes. This gave the interviewee the sense that the author was interested in what was being said. They also provided important keynotes that could be used during the duration of the interview and for additional inquiries when for example quantifications were involved.

The interview ended with some general questions. The author told the interviewee that the answers were very helpful and provided several new aspects to her research. After thanking the interviewee for their support and help, the interview concluded.

In total, the interviews varied from between eight minutes (in the case of a farmer due to limited time) to one hour and forty minutes.

Interview analysis

Transcription

In order to analyse conducted data from interviews, it is necessary to bring data from oral to written form. By creating transcriptions the “direct face-to-face conversation becomes abstracted and fixated into written form” (Kvale, 2007, p. 92).

These transcriptions were outsourced and are therefore not part of this thesis. The relation of interview time to transcription time is about 1:6. The recorded interviews were transcribed word by word by students. They were asked not to summarise the interviews so as not to lose any of the information. By making a transcript of the complete interview, all relevant and even irrelevant information was preserved and made available to the researcher. (Gläser and Laudel, 2010a, p. 193 f.).

Although incomprehensible parts were separately noted, pauses, non-verbal and para-linguistic elements[9], and stopgaps such as "ahm" were not.

The author proofread all the transcripts after they were finalised by the students (who were mostly not familiar with the context and the Australian accent) to ensure accuracy. (Gläser and Laudel, 2010a, p. 193 f.).

Comparability of interviews
A framework of informational data, containing only information relevant to the researcher, can be generated by separating all relevant text into a category system (Gläser and Laudel, 2010b, p. 200) (which are the research issues in this thesis).

For the analysis of transcribed interviews, the first step was to search for relevant and comparable text passages according to the issues from the interview guideline. Labelling and consecutively numbering them in the source text extracted text passages with relevant information.

The second step was to copy those relevant text passages separately into a list that was categorised according to the issues for each interviewee.

While listing and comparing the text passages, it is essential to continuously control validity and completeness. When comparing relevant data, particular commonalities, differences, deviations, and contradictions can be detected. (Meuser and Nagel, 1991, p. 461).

The third step of the interview analysis was an intra-expert-group-comparison of relevant information according to different research issues. Different opinions and similar statements within one and the same expert group were marked.

A summary of statements and an inter-expert-group-comparison constituted the finish of the interview analysis.

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[9] These represent mimic, gestures, coughing, and laughing (Bortz and Döring, 2006, p. 312).

By extracting, categorising and summarising raw data, interpretation and subjective prioritising occurs (Gläser and Laudel, 2010b, p. 202). This is very important to bear in mind since other researchers might gain completely different results from the same raw data due to diverse interpretation and different procedures of the interview analysis applied.

1.3.2 Quantitative Approach

As already stated, the quantitative approach uses measurable data to constitute empirical perspectives.

In the last two decades, technological progress enabled researchers to analyse very complex issues by applying computer-based models, which ought to reconstruct reality with its complex relationships and interdependencies.

The research methodology of mathematical modeling is an approach of economic analysis with the incentive to explain relationships between variables and influences on markets. Those relationships may be causal or indirect. (Jaccard and Jacoby, 2010, p. 177). Mathematical modeling is used to derive theorems or conclusions from assumptions or postulates by applying a "process of reasoning" (Chiang and Wainwright, 2005, p. 2). They are theoretic abstractions from the complex and real world, which enable scientists to "study the crux of the problem at hand, free from the many complications that do exist in the actual world" (ibid., p. 3).

According to Ortlieb (2004), the modeling process can be simply explained as follows: a real world problem or a real phenomenon, which needs to be explained is transferred into a mathematical problem by formulating mathematical terms and equations. This process is called mathematical modeling and creates a picture of reality. With the model, simulations can be carried out to analyse the problem and find a mathematical solution. This mathematical solution is interpreted regarding its relevance to the real world, which connects the theoretic model world with the real world. Finally, the solutions gained from the model are verified and tested in the real world. (Ortlieb, 2004, p. 3).

Simulations depict the behaviour of the analysed system in a model and reconstruct the environment. By considering the model construction and by monitoring endogenous parameters it is possible to obtain new findings and generate knowledge. Simulations are simplified and optimised constructions of systems, which have the goal to either complete already existing or to generate new knowledge. (Wilde and Hess, 2007, p. 282).

Models are reliant on available data, which despite careful data collection may include measurement errors. Therefore, it is important to exactly formulate sources of data as well as model assumptions and limitations to prevent them from misinterpretations and wrong conclusions of model outcomes.

In this research, the mathematical modeling approach is used to carry out scenario analysis, which examines the impacts of different water management policies on irrigated crop production in the case of the MDB.

Knowledge gained from the interviews built the basis for the developing process of the WatIM-Model. The author took into account several types of functions by testing non-linear logarithmic and exponential functions as well as linear functions. Within the developing process model output data were compared with real data. Closest to real data were the model outputs with linear functions. For this reason the author chose to work with the linear functions.

Linear programming models are frequently used in economics and other disciplines such as networks and scheduling (Nash and Sofer, 1996, p. 6). Advantages of linear models are their flexibility in addressing complex research problems such as to find out "economic impacts of water policy changes in agriculture" (Franco-Dixon et al., 2007, p. 2). Additionally, they are often used in practise to find solutions for super-dimensional but also discrete problems (Dempe and Schreier, 2006, p. 13). They involve a linear optimisation function and linear constraints on the variables. (Nash and Sofer, 1996, p. 6).

The linear WatIM-Model interconnects irrigated crop markets with the water market (see Subsection 5.1) and enables an analysis of the impact of WMPs on the production of irrigated water dependent crops and water demand.

A common mistake of researchers using a modeling framework to explain and understand reality is that assumptions and constraints, which are made in the model development process are not clarified to the necessary extent or that they are just "forgotten". The consequence of this is that the model gets accredited with a scope of application, which cannot be objectively justified. (Ortlieb, 2004, p. 1).

When using the results for policy advices, it is very important to keep all assumptions and limitations in mind to avoid misinterpretations and wrong conclusions. This may have severe effects for real problems when for example, the government uses modeling outcomes as advices for WMPs and allocation strategies.

Therefore, the author hereby explicitly points out to carefully consider the conceptual model framework in Subsection 5.1.1, the formulation of the optimisation problem in Subsection 5.1.2, the approach of deriving inverse demand functions in Subsection 5.1.3, sources of input data[10] for the WatIM-Model that might contain statistical mistakes in Subsection 5.1.4, deriving values of available water for irrigation and the water reducing algorithm in Subsection 5.1.6, as well as limitations of the WatIM-Model, which are listed in Subsection 5.1.10. Results gained from the linear WatIM-Model analysis do not claim to mirror reality and can only be used for policy advices by keeping in mind the above listed restrictions.

The reader must also be aware that economic modeling is only able to include measurable data. In this thesis, the author points out that it is not possible to measure environmental benefits and ethical aspects at the present time. However, interests of all water users (which include the environment and aborigines) must be taken into consideration by enlarging perspectives onto non-economic knowledge.

Despite those limitations, when deciding about market interventions and regulations, it is very helpful for decision makers and governments to consult scientific knowledge gained from mathematic models, which are able to explain some of the many interdependencies of reality. With this step, uncertainties about impacts of WMPs may be reduced to a certain extent.

The sensitivity of water and the severe consequences of water management policies to water users and the environment are discussed in the following chapter.

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[10] The author chose the best available sources for data, concentrating on reliable and trustable institutions.

2 The Peculiarity of Water and its Market

An intact and healthy environment is the most precious prerequisite for our life. The ecological economy emphasises the strong connection between the system nature and the subsystem economy. From a human's perspective, nature is a provider of renewable and exhaustible resources. (Petersen, 1993, p. 37 f.).

Water is a sensitive resource that is finitely renewable[11]. The usability of water is highly dependent on the intensity and manner of consumption, on water quality, weather and climatic conditions, as well as technological and financial capacities to modify the quality and to transport water[12]. When the natural assimilation capacity of the nature gets over-stressed, which is the case when the average extraction rate exceeds the average regeneration rate (Ostrom, 1999, p. 39), the renewable resource water is endangered. (Petersen, 1993, p. 38).

In the following it is pointed out that from an economic perspective, the resource water is a commodity with specific and unique characteristics. Subsection 2.2 covers theoretical backgrounds of state interventions[13] and regulations.

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[11] Water is renewable due to the water cycle. Surface water evaporates, enters the atmosphere as condensation and meets the surface in the form of fog or precipitation. One part of precipitation seeps into the soil and becomes soil moisture and after a longer period of time becomes ground water. Another part of precipitation collects in flowing bodies of water (e. g. rivers, streams, and creeks) and naturally drains into the oceans or the runoff collects in non-flowing bodies of water such as lakes, ponds, and pools.

[12] For water treatment and its transportation the input factor energy needs to be highlighted. Besides other input factors (e. g. pipes, labour, and capital), energy is a very cost intensive and resource-consuming input factor in the water sector.

[13] State intervention and governmental interventions are equivalent terms. In the regional case study of the Murray-Darling Basin, one must differentiate between the Australian government, which is the Commonwealth, and the Australian states and territories (which are Queensland, the Northern Territory, Victoria, South Australia, Western Australia, New South Wales, the Australian Capital Territory, and Tasmania). Hence, either state governments or the Australian Commonwealth government intervene in markets.

Additionally, cases of water market failures and what circumstances justify governmental interventions are explained.

2.1 The Characteristics of the Commodity Water

When discussing the economic term good or commodity of water, it is indispensable to clarify the characteristics of water and in what sense the commodity water is used in this research.

The most important characteristic of the good water is its polyvalency regarding environmental, social, and economic needs (Solanes, 2001, p. 263).

Water with its multi-functionality provides many "services" for human beings such as transportation, hydro-electricity, fishing, and water sport activities; it is esthetical and provides a basis for recovery. Water bodies are places for cultural and spiritual traditions. Water is used for drinking water and other purposes by households and as an input factor for production (e. g. as cooling water or agricultural irrigation water) by industries.

Besides those functionalities, which describe water to be a good or commodity for human beings from which usage they gain a benefit, water bodies are the habitat for plants and animals and are a requirement for biodiversity.

Hence, water is polyvalent with diverse and partly competing users. The commodity is unique regarding physical, chemical, and biological characteristics, which are described below.

Public and private good characteristics

Generally, goods can be categorised into public and private goods. Samuelson (1954) defined public or collective consumption goods to be enjoyable by all users "in common in the sense that each individual's consumption of such a good leads to no subtraction from any other individual's consumption of that good" (Samuelson, 1954, p. 387). Hence, public goods are non-rivalry of consumption in the sense of Samuelson. In contrast, private goods can be split and used by different individual users (ibid.) and are therefore rivalry.

Musgrave (1959) differentiated public from private goods by introducing the exclusion principle (Musgrave, 1959, p. 12 ff.). Benefits that users have by consuming pubic goods "are not limited to one particular consumer who purchases the good, as is the case for private goods, but become available to others as well." (Musgrave and Musgrave, 1989, p. 7). As soon as users can be excluded from consuming a good, it is a private one that is usually traded on markets. In cases of public goods, no market exists and therefore there is a total market failure (see Subsection 2.2).

Héritier (2002) enlarges those views on public goods by differentiating them into three categories of common goods: (1) public goods are accessible and non-rival, (2) common pool resources (according to Ostrom 1990) are accessible and rival, (3) club goods are limitedly accessible and rival. (Héritier, 2002, p. 1 f.).

Water is a good that is not produced but can naturally be found in underground resources, lakes, rivers, seas, oceans etc. Water belongs to the group of *common-pool resources* since there is a sufficient quantity. Even though it would be possible to exclude potential water users from water consumption in cases of common-pool resources by for instance fencing lakes or bottling water, it is very cost intensive. (Ostrom, 1999, p. 38). Ostrom differentiates between the *resource system* itself which is a groundwater pool or a lake and the *resource unit* that is the volume, which is consumed or extracted by individual water users (measured in ML, for instance) by appropriation. In many cases the appropriator uses or consumes the *resource units* when drinking one litre of lake water. A second group of appropriators uses *resource units* as an input factor for production when they use the water for irrigation issues. The third group of appropriators immediately transfers the ownership of the *resource unit* to others, who use or consume the *resource unit*. (Ostrom, 1999, p. 40). Water service providers for instance belong to the last mentioned group (see Subsection 3.3.1).

One and the same *resource system* may be used by more than one user by extracting or using *resource units* at the same time or one after another. The *resource unit* itself is not a commonly used or consumed good since this specific unit is not available for other users at the same time. Hence, *resource systems* may be used commonly but *resource units* cannot. (Ostrom, 1999, p. 40).

The more *resource units* are used by water consumers who want to maximise individual benefits, the less water is available for additional water users and the less water stays unused in the *resource system,* which would be important for the ecologic health of the water system.

The tragedy of the commons is a term, which was introduced by Garrett Hardin in 1968 and describes the problem of degradation of the environment when many appropriators commonly use a finitely renewable *resource system* (Ostrom, 1990, p. 2). They focus only on profit maximisation by using more and more *resource units* without acknowledging the condition of the overall *resource system*. "Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons" (Hardin, 1968, p. 1244).

Since scarce water resources result in rivalry and user allocation conflicts (in cases in which demand exceeds supply) the good water must be categorised as a private good. To protect scarce water resources, freshwater water bodies are in governmental or private ownership (at least in industrialised counties). By providing "property rights" for *resource units* (which are in actual fact water rights) for a defined *resource system*, and allowing these rights to be traded on a market by separating them from land, others are excluded from the usage of these units.

In this thesis, the focus is on rural water consumption[14] and the usage of water for agricultural crop irrigation, including the above-mentioned second and third group of appropriators. Therefore, water is treated as a private good with rivalry, exclusive and limited accessibility character.

In the opinion of the author of this thesis, irrigation water for commercial use is not a basic need[15] since farmers may cultivate crops that are adapted to climate and weather conditions and do not need to be irrigated. They could also

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[14] Water consumption and water usage are perceived as equals. The Australian Bureau of Statistics (ABS) defined water consumption to be "equal to the sum of Distributed water use, Self-extracted water use and Rural water use less Water supplied to other users less In-stream use and less Distributed water use by the environment" (Australian Bureau of Statistics, 2006, p. 5).

[15] The term basic needs is defined by the MDBA as the following: Basic needs are "drinking, food preparation and hygiene; water to cover community essentials such as keeping hospitals, schools, emergency services and other key services operating; water for essential commercial and industrial users; and water to maintain, as far as possible, the social fabric of the community." (Murray-Darling Basin Authority, 2010, p. 148).

import water intensive crops from regions that have larger water resources. The author is convinced, that water should be available to every living being (which includes original vegetation and animals as well) for basic and survival needs.

Despite these facts, in the area of water management, the ecologic function of water bodies must be underlined. The preservation of this function can be seen as a public good from which no one can be excluded from usage or consumption. (Stuchtey, 2002, p. 53 ff.). Therefore, qualitative and quantitative standards of water bodies must be protected. If this protection cannot be realised by providing property rights (water rights), which are coordinated on water markets due to market failure, the ecologic functions of water bodies and corresponding quality may be protected by state interventions.

Further characteristics

The volume of usable water is highly dependent on its accessibility: When very deep groundwater sources are used, appropriate technology which can be very energy and cost intensive is needed to bring it to the surface. Water bodies that are not accessible by all users due to very long distances or missing equipment exclude some willing users from consumption.

The usability of water additionally depends on its quality, which is highly influenced by its pollution and salination. Very clean water can be used as drinking water. The usability of less clean water, which might contain sediments, chemical substances, hormones, or other organic or inorganic substances, is highly dependent on the level of pollution and the intended purpose. For instance, less clean water, which cannot be used as drinking water without some form of treatment, could still be used for agricultural needs such as the cleaning of stables or crop irrigation. If the pollution levels are too high water cannot be used without specialised treatment that is more costly. If these costs exceed the benefit of its usage, it would not be cost effective to clean the water.

However, not all benefits of water usage can be expressed in monetary terms. For instance, there is no market and no price for the environment, time or life. Questions such as: What is the benefit of clean water to the environment? or What is the benefit for a fish to live in clean water? remain unanswered. Therefore, the treatment of water may have much higher benefits than economists are able to express in monetary terms.

The quality of water can change due to its consumption. When for example water is used on fields and becomes contaminated by fertilizers or pesticides, the water quality can deteriorate and the scarcity of consumption water is increased. In the case of externalities, "opportunity costs emerge from deterioration of water quality by users" (Burdack, 2011, p. 3), which is further explained in Subsection 2.2.3.

An advantage of modern technology is the possibility to improve the quality of water by treatment or recycling. This gives water users the chance to use water sustainably and prevent environmental damages due to polluted water.

Another characteristic of water is that it has a high mass (Stuchtey, 2002, p. 19). For its transportation, a lot of energy is required unless a gravity flow delivery system can be used. For this reason, transportation is relatively expensive in relation to the price of the good itself. Therefore, water resources that are located close to consumers should be used to reduce distances and costs of transportation. (Oelmann, 2005, p. 15).

Water can be stored to a large extent in water tanks, dams etc. to provide consumption water consistently and more or less independently to natural water flows and precipitation. However, the quality of water can be negatively affected by storage and transportation. Long storing periods should be avoided to prevent degradation of quality due to the accumulation of algae and bacteria.

Water flow is only possible in one direction. Changing the direction could result in water pollution since pipe deposits could become loose and undesirable water chemical reactions could occur. The greater the distance the water has to be transported, the higher the risk of qualitative degradations. Therefore, short transportation methods not only preserve water quality but also ensure energy savings[16]. (Stuchtey, 2002, p. 19).

Another important characteristic for economists is the predictability of the value of water. Economists define the value of a good by giving it a price which should mirror the good's value and its scarcity.

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[16] The source of energy is important as well. Sustainable energy generation (with renewables e. g. wind and solar) is preferable since it does not additionally burden the environment.

From a humans' perspective, the value of water differs between regions, religions, cultures and individual values. To determine the value of water, especially non-use values, methods as the willingness-to-pay approach[17] and the willingness-to-accept approach[18] can be applied. This could however be a very complex undertaking since values are often influenced by the context in which they are used. On the one hand, a person might not think twice about allowing polluted water to drain into a lake in order to reduce production costs but may feel differently if his children wanted to swim in the lake. Similarly, indigenous people who use water for non-consumptive purposes to perform cultural or spiritual acts might not be able to monetarily express the value of the water. Others, like non-human life are understandably incapable of expressing the value.

Therefore, economic research, which monetises values of environmental commodities "is still in a state of flux" (Pearce and Turner, 1990, p. 21). The value of water reflected by economic studies is therefore fragmentary, which is important to mention at this point.

2.2 Cases of Partial Market Failure in the Water Sector

Perfectly functioning markets are devoid of market power. To achieve perfect competition in a market, optimal quantities and prices result from the forces of supply and demand. Additionally, the access to the market is free; information is available and transparent to everyone without restrictions. Those market conditions define the neoclassic allocation optimum. Deviations of this allocative optimum are called market failures. A market fails when its functions and the market equilibrium, in which supply and demand perfectly match and where suppliers realise their maximum profit and demand realises its maximum utility, cannot be found.

In the field of water management, there are several reasons for partial market failures. These include:

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[17] In which the respondents should express how much they are willing to pay for a certain ecological quality or to avoid certain stages of pollution etc. With this approach, a monetary evaluation of a specified ecological quality can be detected. (Fritsch, 2011, p. 143).

[18] Here respondents are asked to monetise their willingness to accept a degradation of ecological quality (ibid.).

1. A lack of information.
2. The water market is vulnerable for market concentrations as a result of network characteristics and barriers to the entry of competitors into the market. In cases of natural monopolies the water market fails.
3. Market failure is caused by the characteristic of water itself. By the usage of water, negative externalities might occur if not all accruing costs are covered by the market price and exclusion is limitedly possible.

These cases will be discussed in the next section and perhaps by understanding why markets fail in their functions, the meaningfulness of state interventions can be understood.

2.2.1 Information Asymmetries

Partial market failure can be a result of incomplete information. This can be two-fold. On the one hand there exist uncertainties, which are neither measurable nor quantifiable according to Knight (Knight, 1964, p. 19 f.).

“It is a world of change in which we live, and a world of uncertainty. We live only by knowing something about the future; while the problems of life, or of conduct at least, arise from the fact that we know so little. […] The essence of the situation is action according to opinion, of greater or less foundation and value, neither entire ignorance nor complete and perfect information, but partial knowledge.” (Knight, 1964, p. 199).

In water markets, these uncertainties often concern the predictability of long-term forecasts regarding precipitation and climate change, the natural assimilation capacity of water and the true value of water (when including environmental, social and economic issues of water).

Even though these uncertainties are not measurable today, they might be measurable in the future as a result of technological advances and knowledge developments.

On the other hand, there are issues that can be measured, however these measurements are susceptible. Knight describes this “quantity susceptible of measurements” to be a risk (Knight, 1964, p. 19 f.). He defines risks to be “the distribution of the outcome in a group of instances [that are…] known (either through calculation *a priori* or from statistics of past experience).” (ibid., p. 233). Hence, risks occur when measurable issues are either measured wrong or not measured at all or data about measured issues are wrongly transferred.

Water market risks occur in the following situations when the data is either incomplete, uncollected or incorrect.

- Total water availability in resource systems and consumption pools (e. g. dam, groundwater)
- Water losses due to evaporation (which are highly dependent on ambient temperature and weather conditions)
- Impacts of water pollution, over-usage or natural abnormalities as a result of natural extremes such as droughts (e. g. how long does it take to fill up rivers?)
- Water demand and volume of water supply for irrigation issues (by e. g. delay in time on trading markets, communication failures between supply and demand, missing or incorrect metering)
- Linkages of water extraction in one region on conditions of water availability and water quality in other regions
- The extent of the pollution of water systems and its health impacts (Boyce, 2002, p. 4 f.)

In cases of risks, interconnecting agents such as institutions, businesses and individuals might help to exchange information easier in the long-term. Furthermore, incentives offered to businesses may encourage them to report truthfully (Perman et al., 2011, p. 240). Investments in the measurement of water (e. g. metering water) may improve data collection and diminish information asymmetries.

Additionally, information campaigns may help to raise the awareness of water users by alerting them to the economic, social, and environmental impacts that may result from unsustainable water consumption.

Regarding water markets, incomplete information (uncertainties and risks) lead to an inefficient coordination of supply and demand and as a result the water market fails. If market prices of water do not mirror its true value and scarcity, water may be over-used as a consequence.

2.2.2 Natural Monopoly

If a single supplier transports water through a network to its customers, it can become more economical and cost-effective especially when it serves the highest possible number of customers in that particular network. The more users share the costs of construction, modernisation, replacement, and maintenance of infrastructure, the cheaper the supply of water for each user. Fixed costs can be shared with all users and the average costs of the supplier are therefore minimised (see the explanation of the economies of scale on the next page). In the water management sector, fixed costs include the costs for pipe installation and pumping equipment, maintenance, storage, and water treatment. Natural monopolies mostly occur when the share of fixed costs to marginal costs[19] is relatively large (Viscusi et al., 2001, p. 314). This makes it difficult for competitors to undercut the prices. The high cost of infrastructure also acts as a deterrent to those thinking of entering a monopolistic market.

Sub-additive cost structure

The necessary and sufficient condition for the occurrence of a natural monopoly is the sub-additive cost structure as the following shows:

The water supply processes can be separated into parts of production X_m (m = 1, 2, …, z) which are exploitation or extraction of water, its treatment and transportation, as well as the delivery of water. The sum of all X_m results in X_M. Hence:

$$\sum_{m=1}^{z} X_m = X_M$$

If just one supplier takes over all parts of production (X_M), total cost function of the monopolist is $C(X_M)$. If production processes would be separated and performed by several companies, costs of those parts of production can be expressed as $C(X_1)$, $C(X_2)$, … $C(X_z)$.

"When a single supplier can procure water more inexpensively than multiple suppliers, a natural monopoly exists." (Burdack, 2011, p. 17).

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[19] "Marginal costs = Change of total costs/Change in quantity. […Hence,] marginal costs [are] the increase in total costs that arises from an extra unit of production" (Mankiw and Taylor, 2011, p. 273).

Hence, the cost function is sub-additive when the total production costs of a monopolist are smaller than the sum of the total production costs of parts of the production $C(X_M) < C(X_1) + C(X_2) + \dots C(X_z)$ and if a minimum of two of the X_m are larger than zero. In that case, the production process is defined as indivisible and the monopolist has the market power. (Fritsch, 2011, p. 164 ff.; Stuchtey, 2002, p. 25 ff.).

With increasing market power and production of a good, average production costs decline in the long term as a result of advantages from the companies' size. Those advantages are also called *economies of scale*, which can be explained technically. By using the same networks and increasing water deliveries, costs which emerge for example from installation of pipes, can more intensively be shared between customers. (Sobania, 2002, p. 34). In the case of economies of scale, a proportional increase of input factors (factor input rates are constant) results in an over-proportional increase of output.

The concept of *sinking average costs* extends the approach of natural monopolies. Here the factor input rates may not be constant. Average costs could also decrease when the change of input factors is partial and not proportional. (Fritsch, 2011, p. 167).

Sub-additive cost functions may exist also if no economies of scale or sinking average costs are present. The provision of quantity produced from a single supplier is more cost-effective than from multiple companies because customers just have to pay the fixed costs once. (ibid., p. 164 ff.). As Figure 1 shows for the one product market, in the case of demand curve D1 a natural monopoly exists. Since the monopolist is a price maker (not a price taker as it would be a company under competition) and chooses the quantity it wants to supply to a certain market price, which is set by the monopolist at the same time, no supply curve exists in a monopoly situation (Mankiw and Taylor, 2011, p. 318).

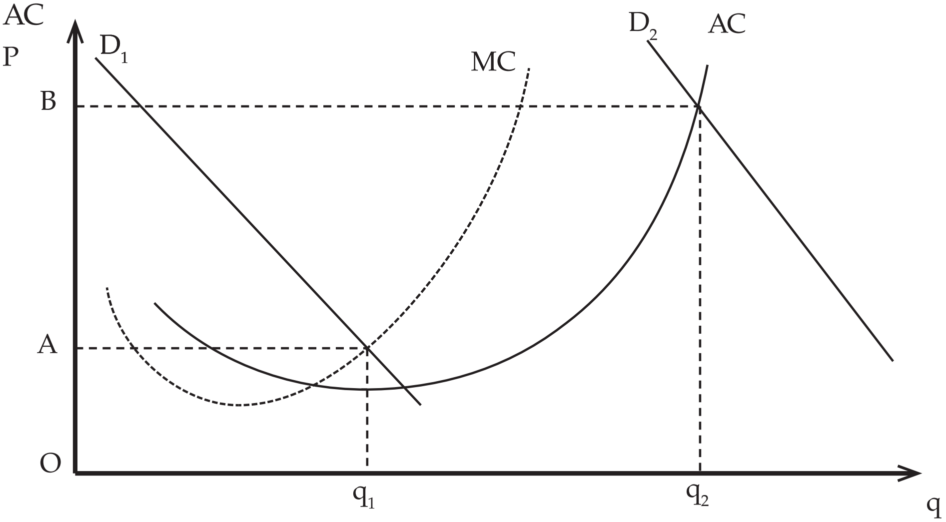

Figure 1: Natural monopoly in the single product case (own illustration according to Knieps, 2001, p. 24 and Stuchtey, 2002, p. 27).

In the case of demand D_1, marginal costs MC exceed average costs AC and economies of scale are already exhausted (since the slope of the MC curve is not negative anymore). Despite this fact, to avoid paying fixed costs twice, demand D_1 is better off to expend increasing marginal costs. Consequently, the quantity q_1 represents customer demand and production can be performed by one supplier with minimum costs ($OA*q_1$). In the case of demand D_2, two companies would supply with lower costs than the monopolist illustrated here since no economies of scale apply anymore and $2*(OA*q_1) < (OB*q_2)$. (Stuchtey, 2002, p. 27 f.). Until a certain point, the monopolist uses input factors up to capacity. When demand exceeds the point, which can be covered by already existing capacities, the monopolist would be forced to invest in new technology and create new capacities. Consequently, an increase of demand results in a growth of the monopolist's average costs and transaction costs (Oelmann, 2005, p. 31 f.); economies of scale are withdrawn accordingly.

Problems and difficulties with natural monopolies

In general, situations of natural monopolies could cause problems in terms of allocative efficiency, productive efficiency, dynamic efficiency, and qualitative efficiency.

Allocative efficiency is achieved when the price of a commodity equals marginal costs with the consequence that the economic welfare is maximised. This is the case in perfect competition since market prices are driven down by competition to a level of marginal costs. (Viscusi et al., 2001, p. 314). Monopolies tend to set the market price high above marginal costs since they gain profit maximisation and they do not have to fear competitors poaching their customers. By setting the price above marginal cost level, allocative efficiency is not realised. In the event the monopolist sets the market prices equal to marginal costs there may be circumstances where costs cannot be completely covered by revenues and a deficit accrues for the monopolist (Fritsch, 2011, p. 173). This might be the case for a water supplier in times of drought since revenues from water sales would unexpectedly decrease.

Productive efficiency applies when input factors are used efficiently and are not wasted. Monopolists might not have incentives for cost savings and use input factors with the highest efficiency (Stuchtey, 2002, p. 30) when no competition forces the monopolist to decrease costs and increase productivity. Employees might use this situation to press for increased wages or to reduce productivity. By governmental intervention, productive inefficiency could be prevented by external control and guidelines regarding cost savings, and service provision.

Qualitative efficiency ensures that product quality reaches the highest standard and addresses the needs and the preferences of its customers. Highest quality, which maximises economic welfare is not reached when a monopolist supplies products of a quality that is claimed by marginal demand and not by average demand. (ibid., p. 30 f.).

Dynamic efficiency is the development of production technology in the course of time (Knieps, 2001, p. 245). Higher standards of production processes and methods of production, improvement of quality standards and development of new products, investment in research and knowledge creation as well as the development of a pioneering role in the markets are characteristics of dynamic efficiency. With the help of dynamic efficiency, companies enable customers to keep or improve benefits and living standards. Technological change could enable humans to compensate e. g. a degradation of environmental conditions and associated shortage of available resources. Monopolies' incentive is relatively small to improve achievements (Peters, 1996, p. 63) and actively gain for innovation since pressure from competitors is missing (Fritsch, 2011, p. 179 f.). The consequence is stagnation in development and technological change with associated losses in welfare.

Furthermore, the occurrence of monopolies could have a strong impact on upstream markets. Depending on the monopolist's decision to increase/decrease the output, demand for goods and input factors, which are upstream in the production chain increases/decreases as well. Upstream input factors in the water sector are for instance pipes, pumping stations, and electricity. Under conditions of perfect competition in the upstream factor markets, a decrease in demand for such input factors leads to losses in welfare. (Stuchtey, 2002, p. 30).

State intervention in cases of natural monopolies

In situations where natural monopolies occur and no potential competition is foreseeable, state intervention seems to be reasonable to avoid the above mentioned inefficiencies and to correct market failures. However, to be able to speak of market failure in the case of natural monopolies two conditions must be fulfilled: that no substitution is available for demand and that sunk costs occur (Oelmann, 2005, p. 37).

Since water has no substitute, the first condition is met. However, in the case of Australian agricultural irrigation water, water supply is not just limited to water suppliers. Farms often practice rainwater harvesting by using on-farm water storages (see Appendix 7.9). This water can be seen as a substitute to water that is provided by water suppliers. However, since the on-farm rainwater storage capacities are limited and highly dependent on precipitation, there might not be any water, during droughts in the farmers' on-farm pools. Therefore, during droughts no substitutions to bulk water are available and the first condition for the event of market failure would be fulfilled.

The second requirement for market failure is the occurrence of sunk costs. Those are expenses that cannot be cancelled or are unavoidable (Brunner and

Kehrle, 2012, p. 257). In the case of water suppliers, sunk costs could include the investment in pipes or water pumps which lie underground or water treatment plants where construction is highly specified and therefore not usable for other purposes. Since the cost of re-allocating these devices to other places would be too high, the costs and investments are sunk and cannot be monetised. Therefore, it is reasonable to speak of market failure in the case of water supplying monopolies and market intervention.

When governments decide to intervene in the water market, market-oriented solutions are more preferable. For instance, such a solution might be the institutional separation of subservices of water supply (by e. g. dividing infrastructure and operation) and inviting competition for some of those subservices.

Furthermore, state intervention is meaningful to externally control quality standards, producers' cost development, and increase productivity. By limiting market power, situations can be avoided in which the monopolist sets the market price too high above marginal costs and water dependent demand cannot be satisfied. Additionally, the expansion of market power of the monopolist on vertically related markets should be avoided and may create a need for governmental intervention.

2.2.3 External Effects

The term external effect is used when the transaction or use of a good directly or indirectly has an impact on market agents[20] who were not involved in the market transaction. Impacts on other agents' utility can be either positive or negative. External effects can occur when exclusion is not possible or too expensive. Using the example of agricultural economy, external effects can be explained as follows:

When animals are sick and are treated with antibiotics, a dairy farmer might use aggressive chemicals to clean the stables. As a consequence, the wastewater

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[20] For the sake of completeness, it must be differentiated between market agents (companies, individuals) and non-market "agents" (the environment, animals, and plants), which cannot participate actively on markets as humans do. Of course, those non-market "agents" also can be affected when external effects occur. But their "loss in utility" cannot be monetised and is therefore not included in economic analyses.

will contain those aggressive chemicals, pathogenic bacteria or germs. If the farmer chooses not to dispose of this polluted water into the wastewater network correctly but chooses instead to dispose of it into a river, then negative effects would occur for all other river water users. Those users could include other market agents such as fisheries or other farmers who withdraw river water directly, individuals who want to swim in the river, or non-market "agents" such as water plants or fishes.

The negative effects of this could include health concerns and the associated costs that must be covered by the health insurances and its members. In this case, the costs that were avoided by the one who caused the pollution (called "polluter" in the following) must be paid by the health insurance and are therefore called external or incidental marginal costs. Costs incurred by the dairy farmer for water usage are referred to as private costs. Social marginal costs are the sum of both the private and external marginal costs (externalities). (Burdack, 2011, p. 12). The above-mentioned example explains one case of the negative externalities in which "market prices are only reflecting private prices; therefore the market price is set too low to cover all costs inclusive of external costs" (Burdack, 2011, p. 13). When the market price does not equal social marginal costs of production, allocative inefficiency applies (Brunner and Kehrle, 2012, p. 368 f.).

In the case of negative externalities where environmental damages and damages to health might be a consequence, the intervention of the government could be deemed necessary. However, governmental intervention would not be meaningful when the imbalance of the market price and social marginal costs of production cause positive externalities as the following example shows. If going back to the previous example, positive externalities would occur if the dairy farmer cleaned the water after usage on his property so carefully (with e. g. technological on-farm sewage plant of highest standard) that the water quality was better than before the usage. In this case, benefit for other water users would increase even though they are not involved in the transaction of the dairy farmer who maintains the sewage plant. In this case, positive externalities occur and the market price, users have to "pay" for river water, is now lower than the benefit they actually gain from the usage. However, the instances where a farmer intentionally increases his production costs to ensure that the consumed water is cleaner than before usage are relatively small.

Potential causes for external effects

Market failures in form of external effects always occur when water rights are not clearly specified or are not effectively enforced. In those cases, the polluter is not paying for negative external effects that result from his or her action. Instead those costs accrue for the aggrieved party. The causes for these external effects are discussed in the following:

Pollutant inputs: by mixing water with organic or inorganic substances[21] which reduce the quality and associated usability of water for other users or damage the environment, pollution of water occurs. If water is polluted and not cleaned by the polluter (or monetary compensations payed for cleaning), negative external effects occur.

Water extraction: when water is over-consumed[22] by some agents, other agents (such as the environment and other water-users that are not participating on the market) experience negative external effects since they do not have the same chance to use the water. Those disadvantaged agents either have to reduce their water consumption to a minimum or must find other sources of usable water. Humans could use technology to increase the volume of usable water by for example desalination and wastewater recycling. However, by using such technological efforts, opportunity costs occur, which must be included in the market price. Besides the occurrence of opportunity costs, environmental damages and salination (a form of water pollution and soil degradation) might be possible consequences if water gets extensively over-consumed. If those consequences are not monetised and covered by the market price the responsible users pay, negative externalities occur.

Transportation: the farther water is transported, the poorer the quality of water due to disconnecting pipe deposits and undesirable water chemical reactions. Additionally, leaking pipes or pipe breaks have flooding effects when the leakage is not promptly repaired. This could have negative effects on that area where the water flows and when soil is incapable of absorbing the excess water. In principle: the farther water is transported, the higher the fixed costs to maintain

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[21] Directly (active usage of water and mix water with other substances for example cleaning out stables) or indirectly (for example treating plants with fertiliser without using water actively. Then rainwater may mix with fertiliser and enter rivers as runoff).

[22] Assimilation capacity of nature gets over-stressed.

those pipes. Leakages and pipe breaks are more likely in areas where the level of repairs and overall maintenance are not of a sufficient standard. Quality degradations and leakages cause negative externalities if they are not included in the water price.

Physical manipulation: are physical characteristics of water, such as PH-value and temperature changed by its consumption (e. g. when water is used as a coolant in industrial production) that may create negative effects for other water users.

Storage: with the storage of water, the natural flow is interrupted, which can have a negative impact on animals and plants that are dependent on a certain flow velocity. Additionally, by storing water, its temperature may change. The longer water is stored, the more its temperature increases under solar radiation. This in turn leads to not only a higher loss of water quality due to algal formation etc. but also to evaporation and water losses that also have negative impacts on the environment and other downstream water users. When the water price for stored water does not cover the above-mentioned negative external effects, institutional intervention could be a solution to correct this misbalance.

External effects can occur quite easily since the characteristics of water quickly connect different water users with each other and pollution spreads quickly when water bodies are not separable. Since clean water is such a rare resource, it must be treated carefully and be protected from pollution and over-consumption. When markets cannot ensure a sustainable usage with this sensitive resource, governments and/or institutions must intervene.

State intervention in cases of external effects

When external effects and consequently costs occur that need to be paid by someone else other than the polluter, the water market fails. In that case, governmental intervention could be meaningful to internalise external costs and to avoid damages to the environment and society.

Boyce (2002) differentiated the relationship between the winners (those that gain higher benefits from pollution) and the losers of pollution (those that must bear the costs of pollution imposed by the polluter). He found that environmental degradation varies in time and location. Reasons for this are threefold:

1. Affected groups may not live in times of pollution but are inheritors of the environmental degradation. In this case, future generations must cover the costs created by polluters of previous generations.
2. Affected groups live in times of the pollution but are not aware of it as a result of information asymmetries (see Subsection 2.2.1). In this case, they cannot prevent the pollution but have to bear the financial burden and consequences, which might occur later on (e. g. health problems).
3. Affected groups live in times of pollution and are fully aware of it, but they are not strong enough or influential enough to prevent the polluters. This may be the case of minority groups such as indigenous people or the environment itself, which do not have a strong lobby or are not able to fight for their needs and physical integrity. (Boyce, 2002, p. 4 ff.).

By state intervention, the polluter may be either obliged to cover the costs by including the costs for pollution in the polluters' cost function (polluter-pays-principle) or the above mentioned "losers" must pay for it (burden-sharing principle). However, if the pollution was caused by previous generations, it might be impossible to trace the polluter. In this case the polluter-pays-principle cannot be applied. (Petersen, 1988, p. 222 f.).

By applying the polluter-pays-principle, the polluter would choose the most efficient solution to minimise his or her costs. In most cases, the prevention of pollution would be more efficient than subsequent removal of the pollution. Simultaneously, (public) awareness for the importance of sustainable use of resources is raised.

When water pollution, which is not clearly specifiable by means of water rights or the polluter cannot be found and no one else is prepared to pay for the elimination of damage, negative external effects occur. (Stuchtey, 2002, p. 53 ff.). Therefore it is important that institutional regulations make polluters responsible for these negative external effects or prevent them from occurring in the first place.

By the provision of a legal system, laws dealing with environmental protection can be provided. By the specification of qualitative and quantitative standards, taxes or pollution licences (Petersen, 1988, p. 222 f.), the protection of water and the environment can prevent damages and control sustainable usage of scarce resources.

Qualitative standards should pick up preferences of all water users (plants and animals included) and define conditions of water quality before and after human usage. Quantitative standards must consider regeneration rates of water bodies (e. g. groundwater exhaustion) and should not exceed sustainable levels, which are tolerable for the environment. The maximum volume of water extraction must be defined. Since water is a scarce resource, conflicts due to over-utilisation occur between all water users. A market-based solution for those conflicts is water pricing, which indicates water availability and includes opportunity costs. That allows users to develop a feeling for the "real" value of water and oblige them to use water sustainably and not to be wasteful. Additionally, determinations of the maximum levels of water extraction (caps) or the provision of quantitatively limited water extraction rights provide possible instruments in cases of threatening over-consumption.

2.3 Fundamentals of the Regulation Theory

The government is involved in an economy in many ways: it raises taxes, spends this money for other purposes, and is responsible for the legal system, which sets the rules for a society in which individuals and companies exist. The government may regulate segments of an economy by for example, imposing restrictions on competition, establishing minimum wages or formulating a pricing policy. The government may control pollution and allocate public utilities. (Viscusi et al., 2001, p. 1).

But what are the legitimate cases and reasons for a government to be involved in the economy? Originally the regulation theory was established to investigate and understand reasons for interventions. It asked for relevance and reasonability of interventions and examined sectors in which the state was typically involved by planning, controlling or even taking over the production itself in the form of public undertakings. Examples of relevant sectors are water and energy, transportation, post and electronic communications. (Borrmann and Finsinger, 1999, p. 8). These are sectors in which the state is intensively involved by regulating market processes and competition. The government generates the legal framework in which transactions are realised.

The regulation theory defines minimum standards, investigates rules and frameworks of institutions, considers institutional arrangements that are relevant for the market, and compares existing with alternative regulating institutions. (Finsinger, 1991, p. 8 f.). Two approaches are differentiated by the regulation theory: the positive and the normative analysis.

2.3.1 Normative Approach

The normative concept of the regulation theory asks the question whether state intervention is actually reasonable and necessary from an economic view (Soltwedel et al., 1986, p. 4). It tries to find out if and how governments *should* intervene in markets (Borrmann and Finsinger, 1999, p. 9). The normative approach of regulation theory explains why the economy is not completely organised by only private sectors as in the ideal neoclassic world but is under influence of the state in most relevant parts of economic systems.

To answer these questions, it is important to carefully examine the reasons for market failures. As already pointed out in the subsection above, partial market failures occur in situations of information asymmetry, monopolistic market control, and external effects. The main characteristic of those partial market failures is that the market relevant commodity is of a private character. In those markets, the government, in most cases, more or less intervenes in markets but leaves the coordination of supply and demand to market mechanisms. Those coordination functions of markets are not feasible in cases of public goods since consumers are non-rivalry, they cannot be excluded or exclusion is not desired when everyone has the same accessibility to the good. Public goods cause total market failure because of allocative inefficiencies (see below). (Petersen, 1993, p. 79).

When concentrating on governmental intervention regarding private goods, one must be aware that not every difference between the ideal of theory and real markets create sufficient reason to interfere in markets (ibid, p. 39). In real markets, the neoclassical static optimum is hardly being met. Therefore, dynamics of market processes should be included in consideration. The new market and competition theory considers a dynamic search-and-development-process in which individual economic plans result in spontaneous trade regimes with a trend to equilibrium. However, if the market is not able to dynamically find equilibrium in which the most efficient companies gain higher market shares and in which market outcomes improve, then the market fails both in terms of the new market and competition theory. (Sobania, 2002, p. 27 f.).

If the market is not able to balance demand and supply in the long-term, governmental interventions may be a solution to correct misbalances. However, when governmental institutions are involved in the market, new misbalances may occur as result of those involvements. A deterioration of efficiency, which is caused by the intervention of the government in markets is called governmental failure or regulatory failure. Main reasons for those regulation-induced failures are insufficient foresights and unintended consequences as a result of state interventions (Perman et al., 2011, p. 246). The line between market failure and governmental failure is very thin. Therefore, it must be carefully examined if the reason for market failures or the market failures itself can be corrected or eliminated by economic policy measures. (Sobania, 2002, p. 27 f.).

In the case of a market intervention, the preferred option should be a market-driven or market-oriented solution. If a failure cannot be corrected or eliminated by such solutions, a replacement of the market coordination and the competitive control by alternative mechanisms becomes economically meaningful. (Bögelein, 1990, p. 224).

According to Musgrave et al. (1975) the following functions of state intervention exist:

Allocation function
The provision of public goods or the process of distribution of public goods pursues certain political goals. Political decisions have an influence on the allocation patterns of public goods. As pointed out above, in cases of public goods exclusion of users are either impossible, too expensive or simply not desirable. In cases of public goods, the market fails completely since no market and no price for the good exists. This leads to the necessity of state interventions since no producer is willing to provide a good, which has no price. The state takes over the provision and allocation of public goods. (Musgrave et al., 1989, p. 13 f.). But also when the good is private and markets exist for the good, which usually take over the function of allocation, governmental intervention might be meaningful

in the case of market failures. In this case, political decisions have an influence on the allocation pattern of the private good as well.

Distribution function

When the political goal is to establish a society of fairness and justice, misbalances of income and assets (which occurred by e. g. inheritance) may be corrected by governmental distribution. As soon as the assets are distributed by governmental interference, the market functions are affected. The main difficulty is to harmonise the situation of individual income and assets with individual ideas regarding justice. (Musgrave et al., 1989, p. 10 f.). For the transfer of income and assets, several instruments such as taxes and transfer systems are practical (Petersen, 1993, p. 80 f.). If taxes and transfers are too large and consequently place a burden on companies or affected individuals, the state may cause a migration of business to countries where fewer burdens or market exist.

Therefore, policy is challenged to balance burdens of economy, which occur due to governmental interference in markets and benefits resulting from distributions.

Stabilisation function

Political objectives could be enlarged to a macroeconomic perspective regarding the goals of full employment, reasonable price stability, and a suitable rate of economic growth. Governmental intervention is necessary when the political goal is to stabilise the economy and prevent or intercept economic regressions. Through the application of stabilising instruments, situations of high unemployment rates and inflations are often softened. One such instrument is the central banking system, which controls money supply or instruments of the fiscal politic with for example public expenditures and taxation systems. (Musgrave et al., 1989, p. 13 f.).

Those three functions of state interventions could trigger the implementation of regulations in an economy.

Furthermore, economic reasons for governmental interventions are justified with particularities of different industries (Sobania, 2002, p. 27). Dynamic economies entail innovations, change of production and technology as well as a change of consumer preferences. Those changes could result in a change in whole sectors and are therefore called structural changes. In cases of disproportions, in which the adaption of the sector is inert and over-capacities or bottlenecks occur, the market becomes misbalanced. When these misbalances result in severe social or economic problems (e. g. unemployment), structural policy measures, which support processes of adaptation, could be reasonable. (Peters, 1996, p. 11). Instruments of structural policy measures can be:

1. preservation subsidies that support the sector by financial help and reduced tax rates
2. price fixing by providing for example minimum or maximum prices
3. supplier protective regimes, which include governmental commitments for products, market access barriers and capacity constraints, protection of vested rights, customs or quantitative limits on imports, or tax burdens for the substituting competition. (ibid., p. 141 ff.).

For instance, the agricultural sector had such structural problems. By technological change and increasing application of fertilizers and pesticides, farmers are able to produce higher quantities of crops. Globalisation increased competition on an international level and low prices for crops forced farmers from small farming with diversification of crops towards agribusiness with monocultures. Those developments resulted in higher outputs but also lower employment rates. Governments support farmers and protect them from international competitors with for example fixed minimum prices and governmental commitments for agricultural products as well as high barriers for food imports from other regions. Those instruments may lead to massive over-production and an inhibition of agricultural market adaptations to changing circumstances.

When applying economic policy measures, it must improve the initial situation (Sobania, 2002, p. 27). Therefore, control of impacts and a constant comparison with the initial situation is highly important. If no improvement can be achieved, a correction or abandoning those economic policy measures is essential.

Since transaction costs occur with each introduction of institutional regulation, benefits resulting from the introduction of regulation must be weighed against occurring costs. (Sobania, 2002, p. 27 f.).

With any institutional arrangement, which intervenes in markets, transaction costs occur. They may include cost results from:

- information acquisition
- creation and enforcement of contracts
- instrument establishment and implementation, and
- controlling the compliance of agreements and targets. (Perman et al., 2011, p. 243).

It is only meaningful to consider economic policy measures when benefits outweigh costs. However, economic policy measures might cause much higher benefits than quantitatively identifiable by economists. This should be taken into consideration when deciding for or against applying regulations that have for example the goal to protect the environment and avoid pollution by water usage.

2.3.2 Positive Approach

The positive analysis of the regulation theory discusses political and historical reasons for the implementation of regulations. Moreover, the positive concept of the regulation theory tries to explain the impacts of already existing regulations (Borrmann and Finsinger, 1999, p. 9).

Soltwedel et al. (1986) argue that in the sense of the positive analysis, regulations mostly have been implemented to correspond with individual interest groups, which hope to gain an advantage. In those politically triggered cases of market interventions, regulations occur without the necessity to correct market failures. (Soltwedel et al., 1986, p. 4).

Each individual has interests and preferences that it tries to follow. In a society, individuals with same interests and preferences may organise themselves in interest groups. The larger an interest group is, the more power it has to push through its interest in a society. This course of action is a critical point of the democratic system because individuals are voters at the same time (Musgrave et al., 1989, p. 152). Politicians aim to satisfy their voters' interests by intervening in markets and providing advantages to those interest groups. Soltwedel et al. (1986) suspect that market interventions are made because politicians try to be re-elected and therefore follow interest groups. (Soltwedel et al., 1986, p. 4).

Policy makers and legislative processes often face lobbying pressure. Ideally, regulations should maximise the welfare of a whole society. Therefore, the interest group where interests should be supported by state intervention may be very large and seen as society representative. This may be the case for large companies as well, when they employ many people and are therefore seen as important for society. (Perman et al., 2011, p. 247).

Another reason for institutional intervention is that politicians just have other ideas for a “better” world, which are not consistent with free market conditions (Soltwedel et al., 1986, p. 4).

Only by acknowledging economic and political reasons for existing regulations can an accurate evaluation of their meaningfulness be made. This strongly connects the positive with the normative concept, which helps to analyse why the water market is highly regulated in most cases.

2.4 Interim Conclusion

Water is the basis of life; a necessity for intact ecosystems and it satisfies basic and additional human needs. The usability of water depends on its quality, which is a reason why water is so vulnerable. Pollution can spread easily into connected water bodies and its treatment and transportation is expensive.

Since the rural water that is used for irrigation issues is defined to be a private good in this thesis, an appropriate market would enable allocation efficiencies. The good water has specific characteristics, which tend to cause natural monopolies, external effects and information asymmetries. In those cases, the water market fails and market intervention becomes necessary.

The positive approach of the regulation theory observes political and historical reasons that are responsible for state interventions. The normative approach of the regulation theory verifies whether those interventions are meaningful and economically efficient.

Generally, in the case of market failure, market mechanism should primarily be supported by governmental interventions, not replaced since this would involve high transaction costs that might outweigh resulting benefits.

In some circumstances regulation may help to improve allocative efficiency. Limiting or controlling market power of monopolies might reduce utility losses for consumers. Regulation instruments, which have the goal to internalise external effects and protect water from pollution and over-consumption might beneficial if the market fails. In this case, governmental intervention that reduce information asymmetries and support the achievement of allocation efficiency might be reasonable.

When discussing the meaningfulness of water market interventions for a certain region, local particularities and influencing factors must be taken into consideration. The variety of factors cannot be listed entirely but are for example water availability and quality, infrastructural network, institutions, legal framework, rural development and water dependency of industry, quantity of (competing) water users, intensity of water usage, and ecologic conditions.

In the following chapter the regional case study of the Australian MDB shows that governmental failures and market failure lie close together. Due to extreme weather conditions in Australia, agricultural production is very difficult to stabilise. This would lead to massive over-consumption without governmental intervention as a consequence of water markets failures. However, governmental intervention may not gain desired effects in cases of governmental failures.

3 Water in the Australian Murray-Darling Basin[23]

This chapter aims to answer the first part of the second research question by identifying reasons for over-consumption of water in the MDB that occur despite intensive regulations of water markets. To clarify reasons for recent and potential state interventions, difficulties are described that arise concerning a stable water supply, which is the basis for a major part of the Australian primary industry. Crop irrigating farmers are highly dependent on water as an input factor and are the main water user in the Basin. The rural water market in the MDB, infrastructural characteristics and sources of irrigation water are explained. In addition, it is clarified how water is allocated and rural water prices are determined in the Basin. This section shows both the positive and negative effects resulting from the intervention of the government and states in the water markets.

3.1 Weather Extremes and Climate Change

Water can be provided in two ways. The first is that nature provides water with its surface and groundwater resources and by precipitation. Natural water supply might be irregular and highly fluctuating due to droughts in times of decreased rainfall or floods due to massive rainfall. Water service providers (who immediately transfer the ownership of the *resource unit* to others) ensure a second way to make water available. They may increase the usable volume of water by recycling or treatment and they provide users with water, which may not have direct access to water resources by providing infrastructural networks.

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[23] Parts of this section were published in Burdack et al. (2011).

Australia is one of the most vulnerable countries in the world in terms of extreme weather conditions. Unpredictable severe droughts as well as frequently occurring massive floods illustrate how nature cannot be relied on to provide the quantity of water needed as the following shows.

Central Australia is a very dry area with only a few days of rain per year. The coastal areas of North, East, and South Australia receive the largest share of precipitation. Whereas precipitation is highest in the northern part of the country, during the summer months due to the monsoon, the southern part gets most rain during the winter months (Bureau of Meteorology, Commonwealth of Australia, 2011a). Therefore, water availability is regionally and seasonally dependent. In addition, extreme weather conditions are difficult to predict. For example the severe drought that lasted from 2001 to 2009 was followed by strong flooding in the summer of 2010. This resulted in Australia's third wettest year on record[24] (Bureau of Meteorology, Commonwealth of Australia, 2011b). The reasons for this weather condition is a recurring air pressure shift between the east Pacific region and Asia called the Southern Oscillation or El Niño (Bureau of Meteorology, Commonwealth of Australia, 2011c).

Droughts and flooding rains are typical weather phenomena in Australia ever since. Three to four year periods of particularly low annual rainfall and drought periods are common feature of the Australian climate. The most severe droughts were "experienced between 1900 and 1903, in the early 1940s and between 1965 and 1968" (Rees, 1982, p. 289). Natural for Australia are not just droughts but also recurring floods as experienced for instance in late 2010 in many regions in Australia (Bureau of Meteorology, 2013).

Those extreme conditions are suspected to increase in the future since climate change will cause substantially less precipitation especially in Eastern Australia (World Water Assessment Programme, 2009, p. 183) as reported by Sanders et al. (2010):

> "In addition to lower average surface water availability, it is expected that the variability in supply is likely to increase in the future with an increased number of extreme events. CSIRO […] mentions that scenarios of climate change indicate substantial reductions in mean river flows and higher flow variability. Results from

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[24] "This rainfall led to a dramatic recovery in water storage levels from 26 per cent at the start of 2010 to 80 per cent at the start of 2011." (ACCC, 2012, p. 27).

> some climate change models project up to 20 % more droughts in Australia by 2030 and up to 80 % more droughts in eastern Australia by 2070. The CSIRO analysis also states that drought conditions […] will become more common in the future [in the MDB]." (Sanders et al., 2010, p. 3).

Those projections were confirmed by the Garnaut Climate Change Review, major declines in agricultural production may occur by mid-century under a no global climate change mitigation strategy. Particularly affected is irrigated agriculture in the MDB where half of its annual output would likely be lost. This development would have huge impacts on food exports as well as depopulation of rural areas. Further presumptions under climate change state the end of irrigated agriculture by the end of the century caused by increasing occurrence of droughts, decrease of median rainfall and a tremendous reduction of runoff in the MDB if no mitigation of greenhouse gases takes place. (Garnaut, 2008, p. 125).

Otherwise, there is a 10 % chance of wetter conditions under a no-mitigation case in Australia. In this case, the northern part of the MDB would have a 20–30 % increase in rainfall by 2050. (ibid., p. 161).

Accordingly, a 90 % chance for a drier climate would affect irrigated agriculture in the MDB tremendously.

Despite such variability of water availability and recurring weather extremes, Australian agricultural industry is a traditional sector and has a leading position worldwide concerning agricultural adaption prospects.

In this thesis, the extreme weather condition of floods is not taken into consideration since observed WMPs have primarily the goal to reduce water usage in order to prevent over-consumption of water especially during droughts. Hence, impact analysis of WMPs is limited to dry years and wet years. In this case, dry years reflect droughts and wet years, excluding floods, represent conditions in which agricultural production is best.

3.2 The Murray-Darling Basin's Main Water Using Sector

The area of the MDB in the South-East of Australia extends over five states[25] and covers 1,059,000 square kilometres, which is 14 % of Australia's land. Australia's three longest rivers Darling (2,740 kilometres), Murray (2,530 kilometres), as well as the Murrumbidgee River (1,690 kilometres) run in the MDB (Australian Bureau of Statistics, 2008b, p. 1). Other smaller rivers in the Basin are Loddon, Goulburn, Lachlan, Paroo, Bogan, Warrego, Culgoa, Macquarie, Namoi, Maranoa, Condamine, Wimmera etc.

"The MDB is an area of national significance for social, cultural, economic and environmental reasons." (Australian Bureau of Statistics, 2008b, p. 1). To be able to relate the importance of agriculture in the MDB to whole Australia, national relevance of the agricultural sector is addressed and water consuming facts are provided in the following.

Agriculture in Australia

The share of the agricultural sector is less than 3 % of the Australian gross value added (GVA)[26]. In comparison, finance and insurance services had the major share on GVA with 11 %, followed by mining at 10 %, and the manufacturing industry at 8 % in 2011–12[27]. The importance of agricultural production for Australia's economy is quite small with a slightly decreasing trend since the GVA's share of agriculture was at least around 4 % in 1993–94. (Australian Bureau of Statistics, 2012b, p. 11 f.).

In contrast to the little share of the agricultural sector to Australia's GVA, its share of water consumption is large. The Australian agricultural sector is the biggest water consumer of all industries and accounted for 65 % or 12,191 GL of total water consumption in 2004–05 (Australian Bureau of Statistics, 2006, p. 9) and was despite the long-lasting drought still the largest water consuming

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[25] 56 % of the Basin's land is located in New South Wales with 597,926 square kilometres, 24 % of the MDB's area is located in Queensland with 259,313 square kilometres. The remaining 20 % of the MDB area is situated in South Australia, Victoria, and the Australian Capital Territory.

[26] GVA determines the value of output less intermediate consumption.

[27] The Australian water year and growing season runs from July 1st to June 30th.

sector with 54 % of total water consumption (7,589 GL) in 2008–09 (Australian Bureau of Statistics, 2010b, p. 2).

In 2008–09, a total area of 409,028,747 ha was used for agricultural purposes in Australia, which is about 53 % of Australia's total area. From this total area for agricultural purposes, an area of 1,760,758 ha was irrigated in the whole of Australia in 2008–09. More than half of this irrigated land (about 53 % in 2008–09) was located in the MDB consuming also more than half of total Australian irrigation water consumption (about 54 % in 2008–09). (Australian Bureau of Statistics, 2010a, p. 7 f.).

Irrigated agriculture in the Murray-Darling Basin

The agricultural sector is the main water user of the MDB in respect of more than 90 % of water used[28] in the MDB. (Australian Bureau of Statistics, 2008b, p. 53).

The MDB is a highly relevant region for Australia's irrigated crop production where 100 % of Australia's rice production, approximately 90 % of Australia's cotton production, and 59 % of Australia's grape production takes place[29] (Australian Bureau of Statistics, 2010a, p. 11 and 19).

Furthermore, the agricultural sector is an important employer in the MDB accounting for 10 % of all employees working in the farm-industry in 2006 (Australian Bureau of Statistics, 2008b, p. 1). Consequently, agricultural production is significant for the MDB.

More than 85 % of land used for rice, cotton, grapes, vegetables, and fruits was irrigated in Australia in 2008–09 (own calculation on the basis of data from Australian Bureau of Statistics, 2010f, Table 1). Half of total agricultural water consumption in the MDB was used by those five crop markets (Australian Bureau of Statistics, 2008b, Table 3.20). Without irrigation, some of those crops could not

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[28] Additionally to the 83 % of agricultural water consumption in 2004–05, 13 % of total water consumption in the MDB was lost in delivery systems. Delivery losses are also called "Water supply industry consumption" from the Australian Bureau of Statistics (Australian Bureau of Statistics, 2008b, p. 53). Since the water supply industry mainly provides water to the agricultural sector, those losses arose in the course of water deliveries to the agricultural industry. Therefore, total water consumption of agricultural sector (including water losses) is more than 90 % in the MDB.

[29] 97 % of area under grape production is irrigated land (Australian Bureau of Statistics, 2010a, p. 11 and 19).

be produced at the present level. Irrigation allows year round production in the Basin including cropping in summer when the temperatures are high. However, in a wet year such as 2010, far less irrigation was needed to grow crops because of the nourishment of natural rainfall.

Land expansion for irrigated agricultural production resulted in an intensification of irrigation and led to environmental damages in the MDB. Over-exploitation of natural water resources lead to a severe decline in water levels causing the drying out of rivers, floodplains and wetlands. This created conditions that were unhealthy where algae bloomed and salinity levels increased (ACCC, 2012, p. 73). Furthermore, a degradation of water quality due to pollution of water and soils occurred.

For instance, the deterioration of the Murray River was caused by long-term intensive irrigation practises even though the water levels were low. The impacts on the annual flow can be seen clearly since the Murray River supplies most of Australia's rice cultivators, which are all located in the Murray region. In 2009, the median annual flow of the Murray River to the sea was just 27 % (Qureshi et al., 2009) of the pre-agricultural flow. Human interference in the natural hydrological ecosystem caused huge environmental problems that are exemplified with the average annual flow of the Murray River in comparison with Australia's irrigated agricultural area in Figure 2.

From 1990 until 2001 when the long-lasting drought started, the average annual flow of the Murray River showed fluctuations due to recurring droughts and floods but had an overall decline. At the same time, the size of irrigated area in Australia increased by almost 39 %. Hence, the high intensity of water consumption for irrigated crop production did not consider the actual water availability in water systems in the past as the example of the Murray River shows.

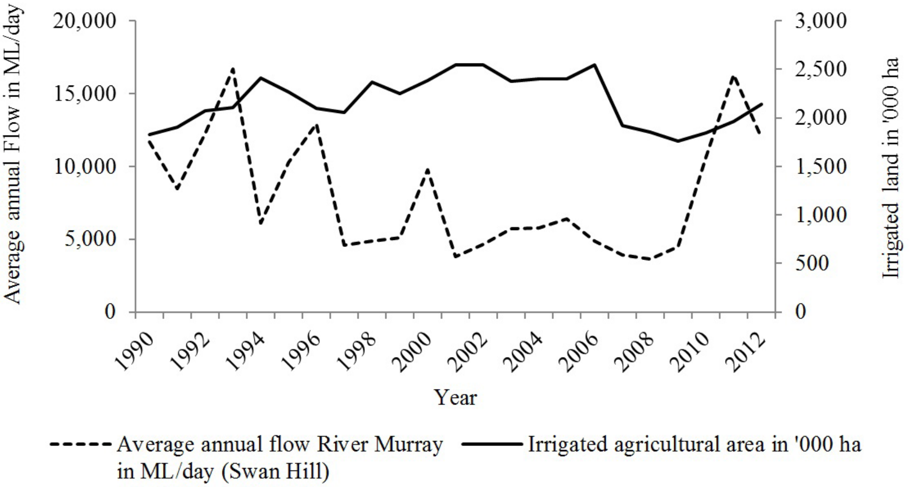

Figure 2: Australia's irrigated agricultural area and average annual flow of the Murray River, 1990–2012 (own illustration, data from Department of Environment and Primary Industries, 2013 and Australian Bureau of Statistics Year Books 1995–2012).

The lowest annual river flow level was in 2007, when the drought peaked. This also resulted in an abrupt decrease in the irrigated area. At the end of the drought in 2009, the river flow suddenly increased to the peak-level of 1993. The main reason for this increase was the flood experienced in the MDB. Another reason might be the RtB program (see Subsection 4.2) and its initial impact on river flows.

To a great extent, the volume of water used varies between crop industries (Bell et al., 2007). Cotton farms used the most irrigation water for cultivation by consuming 2,599 GL in 2000–01 (1,574 GL in 2005–06) followed by rice at 2,418 GL in 2000–01 (1,252 GL in 2005–06). In contrast, irrigation water consumption for grapes was 469 GL in 2000–01 (515 GL in 2005–06), for vegetables was 166 GL in 2000–01 (152 GL in 2005–06) and for fruits was 372 GL in 2000–01 (413 GL in 2005–06) in the MDB (Australian Bureau of Statistics, 2008b, Table 3.20).

At this point one could say that irrigated crop production seems to make little sense regarding the poor water productivity[30] rates (in relation to the agricultural sector's share of water applied to its share of GVA) and environmental problems the MDB experienced. Despite unfavourable conditions for irrigated agricultural production, large quantities of crops were exported as shown in the case of rice (Figure 3).

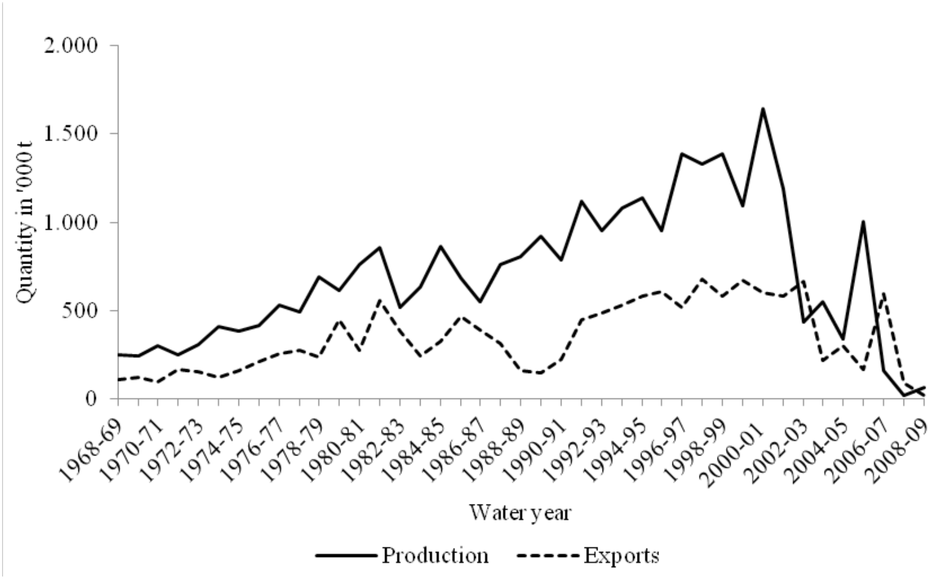

Figure 3: MDB's rice production and rice exports from 1968–69 until 2008–09 (own illustration, data from ABARE, 2010).

From 1968–69 to 2008–09 an average of 69 % (ABARE, 2010) of MDB's rice production was exported. As a result of the long-term drought from 2001 to 2009 when the water price for water rights on the seasonal trading market significantly increased, rice production and exports decreased to a minimum in 2008–09. "Rice goes nearly out of production when the [water] price is high." (Interview with S1).

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[30] "Water productivity might be measured by the volume of water taken into a plant to produce a unit of the output, […] taking both, the quality and quantity into account. […] In general, the lower the resource input requirement per unit, the higher the efficiency." (Hamdy, 2007, p. 10).

Besides its rice exports, in 2011 Australia was quantitatively seen as the world's third largest cotton lint exporter and the fourth largest exporter of wine (FAOSTAT, 2013), which is a high-value product of grape production.

All those crops are mainly cultivated in the MDB. Therefore, water from the MDB is used for crop production that is to a great extent exported.

But is the production of water intensive products in water scarce regions such as the MDB reasonable? The concept of virtual water[31] and comparative advantages are keywords, which are relevant when discussing this question. However, although this thesis does not address this question, since it excludes agricultural trade in its scenario analyses, it should be of interest for future research.

Water used for the production of exported rice was not available anymore in the MDB for other economic or ecologic purposes. The intense irrigation of rice and other crops especially during water scarcer periods led to severe environmental problems due to the over-consumption of water as a limited resource.

Cropping areas and irrigation methods

Crop producing areas in the MDB are quite diverse. For instance, the dominant irrigated crop in southern Queensland (Border Rivers and Condamine-Balonne) and northern New South Wales (Namoi and Gwydir) is cotton. Rice is cultivated predominantly in New South Wales Central Murray and Murrumbidgee. Grapes, fruits and nuts are mainly produced in a number of locations in the Murray region. Vegetables are primarily cultivated in the Murrumbidgee and Mallee region in Victoria. (Australian Bureau of Statistics, 2008b, Tables 3.24 to 3.27). Main irrigated areas in the MDB are in the Murray basin (Bryan et al., 2009, p. 146) between the towns Swan Hill, Albury, Bendigo and Hay, which define the boundaries of the most intensively used areas.

In the southern MDB, cultivated crops are primarily perennials whereas in the northern MDB annual irrigated crops are dominant with higher crop rotations dependent on water availability and rainfall. Irrigation in the northern Basin "is

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[31] From an exporting nation's perspective, traded virtual water is the water, which is used for production of export products (in the agricultural sector: crops and livestock) and therefore not available for other purposes of the exporting country. The possibility to internationally trade food ensures in the sense of virtual water food security in importing countries. (Wichelns, 2004, p. 49).

typically opportunistic and based on the prevailing rainfall patterns". (National Water Commission, 2011c, p. 7).

Despite environmental problems in the MDB and water scarcity during droughts, farmers did not adapt to the extent necessary by applying more water efficient technology. Besides the water price and water availability, irrigation methods in the MDB are highly dependent on the type of irrigated crops. For instance, horticulture farms mainly use drip and micro-sprinkler technologies, broadacre farms mainly apply flood/furrow systems (Ashton et al., 2011, p. 22 and 28).

The application of more water efficient technology is also dependent on farmers' willingness or ability to invest in water saving technology and the development of technological change. Since the willingness or ability to invest in more water efficient technology is still insufficient, governmental subsidies play an important role in the introduction of new technologies on farms in the MDB. As an example, AU$ 5.8 billion was invested in new and water efficiency saving technology in the *Sustainable Rural Water Use and Infrastructure* program initiated by the Australian Commonwealth Government[32] (National Water Commission, 2010c, p. 51). Despite investments in water efficiency saving technologies, the main irrigation method is still surface watering where fields are flooded or furrowed. In 2008–09, a total area of 596,262 ha (64 % of total irrigated area in the MDB) was irrigated with surface (flood/furrow) irrigation in the Basin. The second mostly used irrigation method was above-ground drip or trickle irrigation with 115,452 ha (12 %), followed by sprinkler irrigation (large mobile machines 94,588 ha (10 %) and microspray 33,853 ha (4 %) and other irrigation methods in 2008–09. (Australian Bureau of Statistics, 2010f, Table 19).

Due to water scarcity during droughts, many farmers changed their irrigation methods by applying more water efficient methods. Water saving technologies helped to change from flood to drip, from spray to drip, and from flood to spray irrigation (Interview with PM1). The potential to improve technology in New South Wales is enormous with 55 % of irrigation farmers convinced that they can improve the efficiency of water consumption on their farms (State of New South Wales, Office of Water, 2010, p. 2). However, an interviewed expert limited the potential for technological change on farms by stating that although there

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[32] The Australian Commonwealth (also called the Australian government) and State governments are summarised in the term *the governments* in the following.

was still the capacity to improve in the case of low value crops (pasture, rice, and cotton), but not high value crops. Horticultural farmers with high value crops are more willing to invest in infrastructural upgrades than farmers cultivating low value crops. (Interview with S7).

Farmers' adaption to climate change and extreme events

Generally, interviewed experts assess the adaptability of farmers to be very good and that farmers developed many options to adapt to weather extremes and climate change.

Additionally to the change of irrigation methods, farmers applied methods which helped them to gain more flexibility and to react on changing situations and extreme weather events.

These methods included the use of soil moisture probes and irrigating at night instead of during the day. They also implemented on-farm water storages and on-farm desalination techniques[33] to treat groundwater that originally was unsuitable for irrigation due to the high salinity levels (Interview with F2). Furthermore, farmers recaptured water for reuse, and endeavoured to decrease delivery losses by infrastructural investments.

Moreover, farmers changed the crop type they cultivated, the planting and harvesting windows and the varieties grown. (Interviews with PM1 and S4). Farmers plant different commodities and use opportunity cropping by just cultivating plants when there is sufficient soil water, irrespective to the season (Angus, no year; Interview with S5). In times of drought, they use the most productive areas of perennial crops and retire the less productive ones. They remove old plants with bad root-stocks or use partial irrigation. In cases of annual crops, farmers also have the opportunity to either grow dry land crops such as chickpeas, lentils or legume crops, which need less water (Interviews with S4 and S6a-c) or they may decide to leave the land fallow and sell water rights, which are not used on the water right market (see Subsection 4.2).

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[33] Which is cost intensive since energy is needed for the desalination process and salt must be disposed, which is another cost factor. The extracted salt usually goes into sewage plants (Interview with F2).

Additionally, by plant breeding and genetically modifying plants, farmers were able to produce more drought resistant plants that needed less water (Interviews with F2 and FR2).

Farmers used GPS monitoring in combination with harvested yield mapping to control productivity rates of water and fertilizers (Interview with FR2).

Another adaption method is to use different types of water rights (high and low security rights - see Subsection 3.3.2). With this strategy, the chance of being allocated in times of drought rises. Additionally, they spread water rights for different water sources by owning water rights for groundwater and surface water resources when possible. (Interviews with S5 and FR1a and FR1b). To be able to use different sources of water, they also use different areas for crop cultivation (Interview with FR2). This strategy of risk management gives farmers the chance to still use water from for example underground sources when surface water is scarce in times of droughts.

Experts have various opinions about adaption timing. Some think that the majority of farmers change their farming practises in the short term and then return to previous methods after the extreme event is over (e. g. end of drought) (Interviews with S7 and FR2); others say that farmers plan for the long term too (Interviews with PM1, S7 and S4) and are fully aware of topics like sustainable yields and climate change impacts (Interview with PM1).

In cases of technological change it is unlikely that farmers go back to less water efficient technology since investments are made for long-term adaption.

Since Australia is a very vulnerable country that suffers from extreme weather conditions and the severe impacts of climate change, Australian farming adjustment strategies are seen as taking on a pioneering role regarding water efficiency and flexibility (Interviews with PM2, FR2 and S1). Over a period of time, a water market scheme was established, which helped farmers to be more flexible. The following section gives an overview of the development and the status quo of the rural water market and specifies infrastructural characteristics and cases of market interventions.

3.3 The Rural Water Market in the Murray-Darling Basin

Australia's first irrigation colony was established in Victoria at the Murray River in 1887 (Khan et al., 2009, p. 493). Historically, water was a free good in Australia and the rights to use water, called "water rights [see Subsection 3.3.2] were bound to real estate called 'riparian rights' " (Burdack, 2011, p. 15 f.). In the beginning, this worked well because the initial irrigators were located close to the rivers.

Around 1915, the Government started to build little squared-blocks with horticultural crops (especially in the southern MDB) and offered them to people who had immigrated to Australia after the First World War. Additionally, many soldiers came back from the war and no longer had work. They purchased these blocks to start their agricultural businesses. (Interview with S7).

As the number of irrigating farmers increased, more water rights were provided by the states. However, agricultural production and its water consumption increased so much that water, especially in the MDB, became over-consumed and very scarce, particularly during droughts.

Climate change exacerbates the situation with the result that droughts are more severe and scarcities more intensive. Despite those facts, water extraction by irrigators rose dramatically until 1995. In that year, the water audit clarified the unhealthy situation of the Basin's rivers and water bodies. (Khan et al., 2009, p. 493). In the Council of Australian Government's agreement an MDB-wide cap on the maximum volume of extractable water was introduced in 1994 (National Water Commission, 2011g, p. 48). "The river diversions across all the Murray-Darling Basin were 'capped' at the 1994 level of development. The water diversions corresponding to the 1994 level are about 11,500,000 ML, excluding urban water supplies of about 650,000 ML to Adelaide city" (Khan et al., 2009, p. 494). However, this maximum volume of extractable water (cap) might be still too high in times of drought when less water is available.

Additionally, the Council of Australian Government water reform separated land from water rights and water right trading has been enacted (Murray-Darling Basin Commission, 2008). By this action, the Australian water market was established and water transportation to users that were no riparians to a river or other water bodies was made possible.

The current Australian water market consists of many single markets. Each of these markets is defined by administrative boundaries and water systems, which are geared to for example water bodies or river flows (National Water Commission, 2009). Generally, "water is managed by individual states and territories, which issue water users with water rights" (National Water Commission, 2011c, p. 2). Water rights (see Subsection 3.3.2) define the right to take a certain amount of water for a particular period of time, at a particular location. 82 % of available water rights are rights to withdraw surface water.

Only 18 % of the total volumes of water rights are groundwater rights (National Water Commission, 2010c, p. 14) in Australia. Groundwater resources and groundwater right trade[34] become especially important during droughts when surface water becomes scarce. "Specific areas in the Basin have quite detailed knowledge on groundwater, but in the south areas there is not a lot known." (Interview with PM1). Since groundwater resources are hard to measure (Interviews with S1 and S8) and the estimation of total available groundwater is very difficult, a lack of information (see Subsection 2.2.1) can lead to market failures with the consequence that groundwater may be used unsustainably in the MDB and the price does not reflect scarcity. While Australian aborigines see groundwater as pure water, which should not be touched (Interview with I1), farmers do not want to pay for it since they spent money on the equipment (Interview with S3) and they accept that groundwater is metered and water extraction capped[35] (Interviews with S1, FR1a, FR1b and F2).

To be able to use a desired amount of water, farmers must own water access entitlements (see Subsection 3.3.2). However, actual distributed water depends on water availability and the reliability class of the water right. State governments announce frequently[36] how much water is allowed to be allocated to the water right holders. For both, the water right itself and for actually delivered water the

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[34] "Trade in the Murray–Darling Basin mainly involves surface water access entitlements, rather than groundwater entitlements". (National Water Commission, 2013b, p. 44).

[35] "You have to have a license for a groundwater bore" and there are tight controls on how much water is extractable (Interview with FR1a and FR1b).

[36] In the jurisdiction of the water provider Murrumbidgee Irrigation, the government announces allocation on the 1st and 15th of each month. E. g. on the 1st July 2011, the government

user has to pay a market specific price, which is a result of a long-term plan (see below). Additionally to those planned charges, water rights can be traded on the water right trading market. Therefore, one can speak of two different markets within the water market: the market for water rights and the market for water deliveries (including charges for water right holder).

The particularity of Australia's water markets is that water supplies vary greatly due to extreme weather conditions. Severe longstanding droughts can be followed by massive floods within only one decade as seen from 2001 to 2010. Consequently, planning demand and supply of water is difficult and accurate prediction impossible. Therefore, it is important that the water market is capable of adapting to fluctuating water availability.

In the following, a closer look is taken at the water supply side by clarifying infrastructural characteristics and sources for irrigation water. Furthermore, the Australian water right system and possibilities of water right trading, which should ideally increase farmers' capabilities to adapt to fluctuating volumes of extractable water is explained. The high complexity of the rural water price determination is described in Subsection 3.3.3.

3.3.1 Infrastructural Characteristics and Sources for Irrigation Water

The characteristic of the water market in the MDB can be explained by examining the water supply side in more detail.

Where does the irrigation water come from? Which instances are involved in the rural water providing processes and what infrastructural particularities exist in the MDB? Those questions will be answered in the following.

Water sources

The majority of irrigation water used for agriculture in the MDB originates from surface water and groundwater. In 2005–06, agricultural water consumption in the MDB was 6,499 GL from surface water, 1,069 GL from groundwater and 152

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announces 100 % availability for Town Water, 95 % for high security and 44 % for general security (Power, 2011).

GL from other sources such as "recycled/reuse water and town or country reticulated mains. [...] Over 70 % of the 1,069 GL of groundwater consumption in the MDB occurred in New South Wales" (Australian Bureau of Statistics, 2008b, p. 62 f.). Of the total extracted surface water (6,499 GL), the biggest share was consumed from the Murrumbidgee river with 1,446 GL followed by the Murray-Riverina with 850 GL, the Loddon river with 643 GL and the Goulburn river with 417 GL. Consequently, NSW's share of surface water consumption was the largest with 57 %. (ibid.). Since New South Wales covers the biggest area of the MDB, the above mentioned proportions of water consumption are not surprising. "The decrease in groundwater used as a water source coincides with an increase in surface water consumption" (Australian Bureau of Statistics, 2008b, p. 67). Therefore, groundwater becomes more important for irrigating agriculture in times of drought when surface water is scarce.

Involved instances

In the MDB, some water providers are involved in the water management process. Therefore, rivers must be differentiated between regulated river systems and unregulated rivers as outlined in Figure 4. As Jones et al. (2007) explains, most major rivers in the MDB "are regulated meaning that their supply is controlled or augmented by releases from publicly owned dams and weirs. In contrast, unregulated rivers have no such public infrastructure to control (i. e. regulate) river flows to users and this results in highly variable flows that are solely dependent on climatic conditions in the catchment." (Jones et al., 2007, p. 305).

Unregulated river flows are not controlled or manipulated by harvesting and storage for example. The extraction of water from unregulated rivers is subject to a number of restrictions such as "minimum flow conditions, maximum daily extraction, and extraction timing" (National Water Commission, 2011c, p. 2). Those restrictions are designed to protect the environment when flows are low to moderate by quantitatively limiting water consumption (Jones et al., 2007, p. 306).

In cases of unregulated systems, irrigation farmers extract water "as permitted by jurisdictional arrangements" (ACCC, 2012, p. 16 ff.) Farmers located close to rivers or creeks pump the water directly from these sources. Most farms have big on-farm storage facilities to hold the water from these water sources. They are also replenished by rainwater (Interviews with S7 and F2). In the case of hobby farms, on-farm dams are sometimes used however this is more for aesthetic reasons. Most of the on-farm dams were empty during drought. The result was that it took longer for the rivers to be replenished during the wetter periods because the farms captured the rainwater before it entered the rivers. Since little run off of farm phosphates from the fertilizers and salt entered the rivers, this was interpreted as an advantage. (Interview with S7). However as a consequence, soil quality decreased rapidly, which affected groundwater quality.

Since a lot of on-farm storage is not regulated, environmental impacts cannot be estimated (Interview with S7). In 2011–12, 771,665 ML (approximately 13 % of total agricultural water consumption) of water was taken from on-farm dams or water tanks in the MDB (Australian Bureau of Statistics, 2013b, Table 2). The main advantage of on-farm storage is that this water can be used later in the growing season when water extraction from the unregulated rivers is forbidden due to low river flows (Jones et al., 2007, p. 307).

Farmers who extract water directly from the water system without using services of any water provider are called private diverters and are accountable to the group of self-consuming appropriators. As reported by the Australian Competition and Consumer Commission, private diverters dominate the northern MDB (ACCC, 2012, p. 18).

In addition to unregulated water systems there are systems that are regulated by infrastructural devices such as dams, pipes etc., which are provided by bulk water operators and irrigation infrastructure operators (IIOs).

Bulk water operators harvest, store, and transport water to their customers who are farmers (regulated private diverters) or IIOs. IIOs' customers are farmers who are not directly located on a river or water system but need to be connected to the water source by a network. The network systems of the IIOs may be comprised of pipes, open channels as well as pumps if no gravity can be used for water transportation. (SunWater Limited, 2012, p. 3).

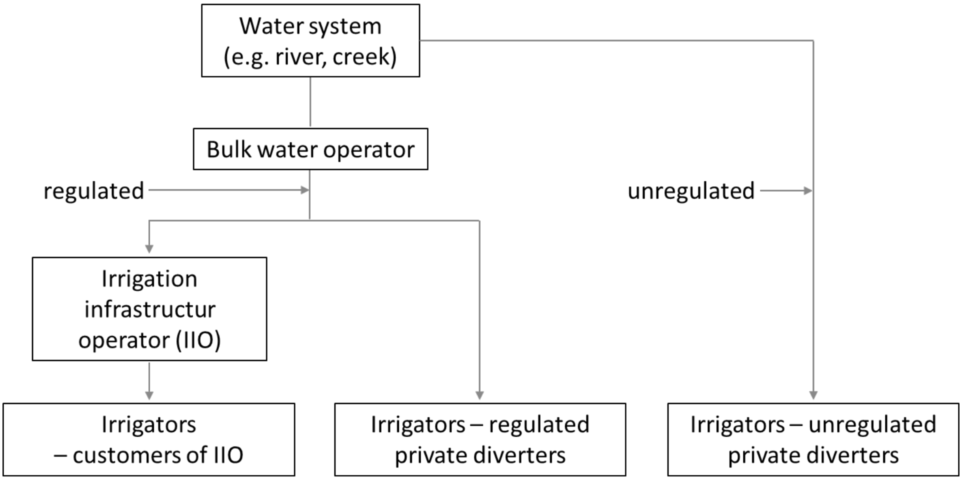

Figure 4: Irrigation water supply chain in the MDB (own illustration according to ACCC, 2012, p. 16).

Bulk water operators and IIOs (hereafter both are summarised as water service providers) are monopolists in their irrigation district since those water suppliers provide their services in different geographic districts without competition (ACCC, 2012, p. 22). Originally all water service providers were State Government departments, but over time, some of these departments have been privatised (Power, 2011).

Infrastructural particularities

Irrigation schemes differ quite significantly between the northern and southern MDB. In the South, a lot of irrigation schemes exist, which were originally set up by the government and then gradually privatised. “The schemes were all channels and canals and a lot of engineering went into setting them up. If you look into a map there will be roads around but most important there is a channel and then off that will be canals and then all the farms, little squared blocks that feed off that.” (Interview with S7). In the northern areas of the MDB, more unregulated schemes occur. These are primarily large farms but unlike the little squared blocks in the south, they are of assorted shapes. Farmers in the north built their own irrigation systems. (Interviews with S5 and S7).

To measure the amount of water extracted from the system, meters are provided for regulated and unregulated water users. The costs of AU$ 6,000 to AU$ 40,000 for the installation and provision of one metering system are covered by the water provider. Costs of meter reading and continuing maintenance have to be paid by the water user. (ACCC, 2012, p. 59). Not all diversions are metered (Interview with PM1 and Murray-Darling Basin Authority, 2011a, p. 6 ff.). When no metered pumps or measured off-take channels are used to determine the volume of extracted water, two approaches are applied in practise. The first is based on regional surveys and estimates diversions on the basis of the area planted or on the duration of diversions. Here the accuracy is ± 20 %. The second approach is based on user returns "which have proved to be very inaccurate" (Murray-Darling Basin Authority, 2011a, p. 6 ff.) with ± 40 %. (ibid.) The incentive to lie about water consumption is very great since this will decrease the farmers' marginal costs (Perman et al., 2011, p. 240), which is a rational profit maximising behaviour even though it is ethically questionable. The intentional falsification of information is an indication of market failure (see Subsection 2.2.1).

Since the accuracy of water metering systems is ± 5 %, it would be desirable to implement such meters for all water users. In some catchments, the metering rate is very poor. For instance, "in the Condamine catchment area, approximately 50 % is metered" (ibid.). Additionally, "a lot of old-fashioned meters [exist] which accuracy people debate" (Interview with PM1).

For this reason, it is difficult to enforce environmental protection and market regulating policies when no accurate measurement is possible yet.

Those measurement irregularities are one of the reasons why water is "statistically" lost. When the water supplier's volume of water deliveries and the customer's declaration about water diversions mismatch because the estimated diversions of the farmer were for example 40 % less than the actual diversions, a gap of 40 % occurs. In this case, the "statistically" lost water is 40 % of actually delivered water. Such high differences can lead to problems since the farmer is not paying for the "lost" water and the water provider registers a loss in revenues. As pointed out before, it was estimated that 13 % of total water consumption in the MDB was lost in 2004–05 (ACCC, 2012, p. 11).

Those losses cannot entirely be explained by inaccuracies with measurements. Losses can also occur due to leaking pipes, evaporation, etc. Evaporation losses mainly occur in dams or open channels. In the MDB, it was estimated that 167 GL were lost by evaporation, which is 0.6 % of the total Basin storage capacity or 32 % of total water consumption in 2009–10 (Murray-Darling Basin Authority, 2011a, p. 69).

SunWater analysed its system losses and came to the conclusion that the "primary sources of controllable distribution losses included leakage from channels, pumps and/or broken pipes, un-metered or uncontrolled use and 'dumping' of water (emptying channels or pipes) for maintenance to occur." (SunWater Limited, 2012, p. 3). Hence, most of controllable system losses could be prevented by investments in infrastructural maintenances and an expanse of metering.

Despite high investments in pipe reparations and maintenance, system losses were estimated to be 13 % of the total water consumption[37] in the MDB in 2004–05. When costs for maintenance exceed costs caused by water losses, incentives for investments are small. Those incentives rise when regulations stimulate monopolistic water suppliers to minimise water losses by for instance legal requirements.

Since water users hold permanent water rights (water access entitlements – see the following subsection) that define a certain share from a specified consumptive pool (which also applies for storages such as dams), some water suppliers also own water rights to account for distribution losses (SunWater Limited, 2012, p. 3). This is mainly done in Queensland and Victoria. However, the National Water Commission states that "Irrigation infrastructure operators may either hold a bulk entitlement, or manage water, without owning the entitlements" (National Water Commission, 2010c, p. 19). By holding water rights and managing water at the same time, water losses would not affect water users and would have no consequences. In those cases, the incentive of the water supplier is small to invest in higher standards of technique or in infrastructural maintenance. An interviewed farmer stated that the channels are between 50 and 60 years old and should be renewed to be more efficient (Interview with F2). Additionally, the incentive to spend money on water saving technologies and infrastructural maintenance are limited without competition.

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[37] Total water consumption in the MDB was 1,246 GL in 2004–05 (ibid.).

The governments initiated several programs to minimise water losses and increase water efficiency. For instance, the *Sustainable Rural Water Use and Infrastructure* program initiated by the Australian Commonwealth government provides AU$ 5.8 billion over a 10 year period for investments in irrigation infrastructure by applying water efficiency saving technologies (National Water Commission, 2010c, p. 51). The Private Irrigation Infrastructure Operators Program is funded by the Australian Commonwealth government and has the goal "to improve the efficiency and productivity of water use and management, both off- and on-farm, by private irrigation infrastructure operators" (ACCC, 2012, p. 96).

Mostly, the governments argue that those subsidising programs are implemented to follow goals of sustainability and protection of the environment by water savings. But it could also follow the objective to subsidise irrigated agricultural production in the MDB by providing affordable water prices. With those governmental subsidies, the water price does not include costs for maintenance. Therefore, external effects occur since tax payers provide the money the governments need to invest in infrastructural programs. Those tax payers are not all involved in the water market processes but close the gap between social and private costs (see Subsection 2.2.3).

On the one hand, those subsidising programs disburden water suppliers and cover their costs to a certain share. Since the price of irrigation water is cheaper because it does not reflect real costs of water service providers, farmers are supported as well.

On the other hand, the governments take over part of the supplier's responsibility for the maintenance of infrastructure. This results in fewer incentives for monopolists to invest in infrastructure, which in turn might cause water losses. In those cases, governmental intervention creates other water market problems.

3.3.2 Water Rights

Water rights are "rights protected by law which legalise agents to use water. These rights define the volume of water that is allowed to be used." (Burdack, 2011, p. 15 f.).

Water rights have two functions. The first one is to take over a structural role by giving water users the guarantee to be able to use a defined volume of water by excluding competing users. Furthermore, with the opportunity to trade water rights, re-allocating of water from one user to another is possible. The second function of water rights is a regulatory one, preventing water resource systems from degradation in the case that many appropriators commonly want to use a finitely renewable water source (see the tragedy of the commons in Subsection 2.1). (Solanes, 2001, p. 264 f.).

In Australia, water rights for unregulated private diverters are called licences, which legitimate the private irrigator to extract a limited volume of water, according to the regional water sharing plan.

Prior to 1994, those water rights were bundled to land. Consequently, the quantities of water rights available on the water market today have an historical background.

Water rights for agricultural irrigation from regulated water systems are differentiated between water access entitlements and water allocations. They are defined by the National Water Commission as follows: Water access entitlements (symbolically illustrated with a bucket in Figure 5) are permanent rights "to exclusive access to a share of water from a specified consumptive pool as defined in a water plan" (National Water Commission, 2010b, p. 3). An example of a consumption-pool is a water storage such as a dam, a groundwater resource system or a whole river.

Water allocations are seasonal water rights (blue filled area of the bucket in Figure 5) specifying a "volume of water allocated to water access entitlements in a given season and/or given accounting period" (ibid.). These seasonal withdrawal rights depend on the total volume, which is announced to be extractable by the state governments. These seasonal announcements take into account available water within the consumption-pool and can be different in every season. (ACIL Tasman, 2004, p. 25). Total water allocation must not exceed the maximum volume defined in accordance to water sharing plans (cap).

Irrigators and other rural water users must own water access entitlements to be able to receive water allocations. Their allowed seasonal water consumption is limited to the volume of water allocated as illustrated in the figure below.

Irrigator A holds the same water access entitlement as irrigator B. Both get 50 % of their water access entitlement allocated. Irrigator A actually uses 50 % of the possible water allocation; irrigator B only uses 40 % of it.

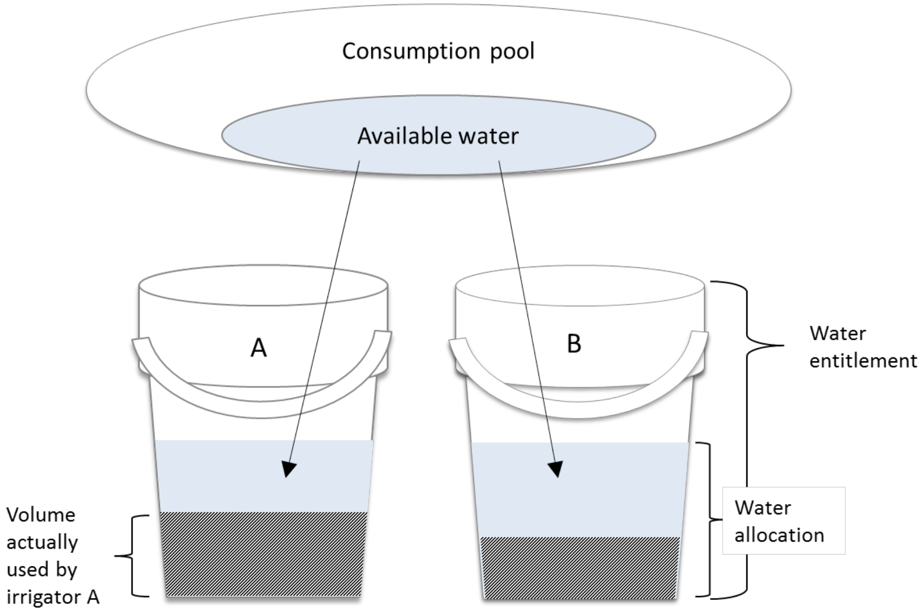

Figure 5: Water right types in the MDB

In situations of droughts, not all water access entitlements can be provided with water. Water access entitlements in the MDB are classified into two reliability classes. *High security* and *general security*[38] water access entitlements are delivered differently with water if water availability in the consumption-pool is lower than the volume held by water access entitlement holder. Within this pooling arrangement, every water access entitlement holder of one and the same reliability class has the same status and allocations are made in proportion to the number of water access entitlements held[39]. (Young, 2010, p. 8).

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[38] These reliability classes of entitlements are denoted differently in other Australian states than New South Wales. For example in South Australia high security entitlements are called *water holding licenses*, and in Victoria *water rights*. General security entitlements are called *water taking licenses* in South Australia and *diversion licences* in Victoria. (Shi, 2006, p. 233).

[39] Assuming there is just one reliability class.

High security water access entitlements have between a 95 % to 100 % chance of being allocated with water. General security water access entitlements have lower reliabilities and are only allocated after high security water access entitlements have been met completely. (Shi, 2006, p. 233 ; Peterson et al., 2004, p. 5 ff.; Grafton et al., 2009, p. 6 f.).

Farmers cultivating perennials usually have high security water access entitlements to reduce the risk of their plants dying during dry periods; however rice farmers usually own general security water access entitlements (Interview with S1).

When the long-term drought had its peak in 2007–08, even high security entitlement holders were affected quite intensively (Interview with S6a-c). Only between 30 % and 55 % of the volume of water access entitlements could be delivered to high security water access entitlements in New South Wales, Victoria and South Australia. Because of the drought, general security water access entitlements were for the most part not allocated for a majority of 2007. (National Water Commission, 2008a, p. 5). Due to delivery risks during droughts, water access entitlements are officially defined as a certain maximum of volume, in practice they are more seen as a share of available water and the according volume (Young, 2010, p. 9).

One interviewed farmer addressed the concerns of farmers who owned water rights but did not receive water during times of drought and spoke of the unpredictability of the farming industry and how difficult it was as a business (Interview with F2).

Given the variability of water availability in the MDB, sustainable water allocation between competing water users that include irrigators, households and industries is difficult to achieve. In the long-term, intensive water usage is only acceptable if the environment and natural water resources are not exploited and do not cause any irreversible damages.

Considering limited water resources, the formulation of legal rights is meaningful since this entitles the owner to the water right, while excluding others from consumption.

Economists and politicians consider tradable, transparent, secure and actionable water rights as an opportunity to improve the allocation of water between competing water users (Freebairn and Quiggin 2006, p. 295). In the MDB, the environment is recently seen as a water user as well, for which the Australian government participates in the water markets by buying water rights from willing sellers to "give the water back" to the nature.

In order to manage a situation where scarce water resources have to be shared by different districts with different regulatory responsibilities, water allocation must be coordinated properly. To establish sustainable water management in the MDB and to protect the ecosystem from over-consumption, different water-trading market reforms took place since 1994.

The Australian legal provisions authorise the Crown to use and control water. The state governments are liable to manage water resources with the help of legislation and policy (Shi, 2006, p. 233) until the Basin Plan becomes active and the MDBA takes over responsibility of water management in the Basin.

The following section discusses whether the Australian water right trading market is operational and leads to sustainable water usage. Additionally, the functioning of water right trade and aspects of water right pricing are described. Even though the Australian water market is one of the most sophisticated water markets in the world, there are still substantial barriers which are described below. Finally, it is discussed what effects water right trading has and whether the Australian trading system is applicable to other countries in the world.

3.3.2.1 Trading Water Rights in the Murray-Darling Basin[40]

Water right trading is the trade of water rights (Young, 2010, p. 16) within one region or inter-regionally. Trading water rights helps to gain allocative efficiency by providing the highest value user with water.

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[40] Parts of this subsection and parts of Subsection 4.2 are in modified form published in Burdack, D. (2011): The Australian water trade. In: Kowarsch, M. (Hrsg.): Water management options in a globalised world, Kapitel 14, Proceedings of an international scientific workshop, Bad Schönbrunn, http://www.hfph.de/igp/proceedings2011 and intended for publication in GAIA. Both articles are based on this chapter of the PhD thesis.

Trade is helpful to manage water during scarce periods (Interview with S8) and has actually facilitated the adjustment of farmers during this time (Interview with S4). Additionally, it is seen as the possibility to buy water allocations to supplement the farmers' amount of extractable water (Interview with S5) and to make money out of water sales when farmers do not need the water.

As already clarified before, water right trading was enacted in 1994 by the Council of Australian Government's agreement. This separated water rights from the land. Initially, water right trading was limited to trades within one irrigation system. In the course of time, trading rules permitted an inter-valley trade. (Murray-Darling Basin Commission, 2008, p. 43). In 2004, the National Water Initiative formed the next water reform step towards today's water right trading market in which the Australian territories/states and the Commonwealth agreed to an expansion of water markets across regional boundaries and state borders (National Water Commission, 2010b, p. 2). With this initiative, water right trading is possible within connected river systems, which can be seen as an expansion of the water market with the advantage that monopolistic providers' structures (regarding services of water metering and water deliveries) are loosened.

For interstate trades a method called " 'tagging' [is used that] tags the entitlement in its state of origin for use in the state of destination. The entitlement retains its source characteristics and allocations, but water is extracted in the state of destination." (National Water Commission, 2010c, p. 6). In the state of destination water extractions are measured. Water invoices are issued by the state of origin, which may include service charges for metering and water deliveries from the state of destination. (Murray-Darling Basin Commission, 2006b, p. 22).

The Water Act 2007 (Commonwealth) defined that state governments and the MDBA create a strategic plan, which sets quantitative limits for water usage (caps) from ground and surface water resources to account for sustainable water allocation. ACCC is encouraged to provide recommendations on water right trading rules to enable the MDBA to develop the Basin Plan (see Subsection 4.1.1) for the MDB. The MDBA detects risks of water resources and establishes trading rules for the MDB. (National Water Commission, 2009, p. 6).

At the beginning of water right-existence, most of these rights were not activated and were therefore called sleeper water access entitlements. After most sleeper water access entitlements were offered on the water market, trade between agricultural producers increased, with water low value users[41] such as rice farmers selling their water rights to water high value users such as grape farmers to gain higher profits (ACIL Tasman, 2003, p. 12; Tisdell et al., 2002, p. 87). Trade enables the achievement of allocative efficiency when the market price for water access entitlements equals social marginal costs.

Water rights can easily be traded between sellers and buyers by using the internet without time delays. Water plans, trading rules, and legislation constitute the framework in which the trade of water rights takes place. Water right trading is facilitated by intermediaries in Australia's water markets. These intermediaries can be lawyers, water exchangers, or water brokers and coordinate water sellers and willing buyers. They provide transactions and information services on the internet for example. Activities of intermediaries are unregulated with the consequence that no barriers exist to enter the market as an intermediary. (National Water Commission, 2009a, p. 19).

In some Australian territories/states[42] participation on the water-trading market is only possible for those who own land and are able to demonstrate a use for water (National Water Commission, 2010c, p. 190 and 215) to prevent speculations. In other territories/states, non-landholders and speculators are able to buy and sell water rights by participating in the market.

Water access entitlement trades primarily involve surface water rights rather than groundwater rights. (National Water Commission, 2010c, p. 35).

Water access entitlements and water allocation rights are typically traded between entities such as irrigators, water infrastructure operators (authorities), and environmental water managers (National Water Commission, 2010a). Besides these market participants, the Australian government contributes in the market to buy water access entitlements from willing sellers within the *Water for*

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[41] The author derives the definition for water low value users from the proportion of Gross Value of Irrigated Agricultural Production (GVIAP) to quantity of used water for production which is below AU$ 1,500/ML (called water productivity in this thesis). GVIAP is defined by the Australian Bureau of Statistics as "the gross value of agricultural commodities that are produced with the assistance of irrigation." (Australian Bureau of Statistics, 2010c) – see Appendix 7.6 for detailed definition. Consequently, water high value users' water productivity is above AU$ 1,500/ML. Rice and cotton are classified into water low value crops. Grapes, vegetables, and fruits are water high value crops regarding its water productivities.

[42] Northern Territory, Western Australia and Victoria (National Water Commission, 2010c).

the Future program (see Subsection 4.2). For instance, in the water year 2009–10 the Australian government acquired 415 GL (426 GL in 2008–09) of water access entitlements (National Water Commission, 2010c, p. 7 ff.). Governmental participation is one reason for the high level of water access entitlement trade, which accounted 1,800 GL (2008–09) and 1,949 GL (2009–10) national-wide (ibid., p. 28). Without market participation of the Australian government, trades of water access entitlements would have fallen from 2008–09 to 2009–10 (National Water Commission, 2010c, p. 5). Consequently, the Australian government has major influence on water demand and therefore the market price of water access entitlements.

Temporary and regional differences

Trading transactions occur mostly in the Australian summer between October and March and are therefore not constant throughout the year. In peak times, hundreds of trades may be handled within only a few days. (National Water Commission, 2008a, p. 2). Hence, water right trading is most active during summer months when water is rather scarce in Eastern and Southern Australia and when the water price for water allocations increases.

The intensity of trading activities varies widely between different regions in Australia. A concentration of trades can be found in the MDB with more than 94 % of the volume of water rights transferred in total Australia (National Water Commission, 2013a, p. 8). But also within the MDB there are regional differences since most trades occur in the southern MDB in which 81 % of the MDB's total volume of traded water rights takes place (National Water Commission, 2013a, p. 8 and Interview with FR2). The southern MDB is the major market place for water right trading since this region is the main connected water system in Australia and therefore particularly suitable for water right trading (National Water Commission, 2010c, p. 5).

The concentration of trading activities in the MDB where between 83 to 93 % of all water access entitlement trades and between 87 to 98 % of all water allocations traded from 2007–08 to 2011–12. This is illustrated in Table 1.

Table 1: Volume of traded water access entitlements and allocations in the MDB and total Australia

Water year	**2007–08**	**2008–09**	**2009–10**	**2010–11**	**2011–12**
Water access entitlement trades					
MDB	770 GL	1,598 GL	1,818 GL	999 GL	1,219 GL
Total Australia	920 GL	1,800 GL	1,949 GL	1,204 GL	1,437 GL
Allocation trades					
MDB	1,393 GL	1,953 GL	2,301 GL	3,417 GL	4,216 GL
Total Australia	1,594 GL	2,158 GL	2,495 GL	3,493 GL	4,297 GL

Source: National Water Commission, 2013b, p. 5 f.

The development of the traded volume of water rights varies. While the volume of traded water allocations permanently increased since 2007–08, the volume of water entitlement trades has fallen by more than 38 % in 2010–11 in comparison to the previous year. This is primarily caused by an abrupt decrease of governmental purchases with the scope of the RtB program (see Subsection 4.2) and the end of the long-lasting drought, which was followed by devastating floods in many regions of the MDB (National Water Commission, 2013a, p. 14). The market price for water access entitlements has minor impacts on the traded volume of water access entitlements as described later in this subsection.

Water right trading is only possible when water bodies are connected. Even though the southern connected MDB is the major market place for water access entitlement trade, interstate trade of water access entitlements is still not popular. In 2007–08, only one transaction of 200 ML was performed between states in the MDB (National Water Commission, 2008a, p. 6). In 2008–09 and 2011–12, there were no interstate water access entitlement trades recorded national-wide (National Water Commission, 2009, p. 5 ; National Water Commission, 2013b, p. 6). In the water year 2009–10, a total volume of 662 ML was traded across state boundaries with only a few transactions from New South Wales to South Australia and from New South Wales to Victoria (National Water Commission, 2010c, p. 6). In 2010–11, 100 ML were traded from New South Wales to Victoria (National Water Commission, 2011h, p. 29). Interstate water access entitlement trades would be a possibility to connect separate water trading markets and increase competition between water suppliers. Trading barriers (which are illustrated in Subsection

3.3.2.2) might hamper interstate water access entitlement trades and let water access entitlement trading markets remain separated in the MDB.

In contrast, water allocation trade between states accounted for 28 % (2008–09) or 19 % (2009–10 and 2011–12) of total traded water allocations. Most interstate trade was downstream. In 2008–09, New South Wales was a net exporter[43] of water allocations, whereas South Australia was a net importer. (National Water Commission 2009, p. 5 , National Water Commission 2010c, p. 6 and National Water Commission 2013b, p. 6).

In general, regional differences in trading activities are caused by trading barriers and differences in surface and groundwater resources. About 25 % of all existing Australian water access entitlements are groundwater rights (National Water Commission, 2013b, p. 21), which may be traded but remain bundled. This means that groundwater rights are bundled with land and cannot be sold without selling the land that is connected to the groundwater source. Since data for groundwater trades is incomplete, the extent of groundwater trades cannot be quantified nor regionally differentiated.

Water right trading price differences

The total value of turnover of water access entitlements was approximately AU$ 1.5 billion and total sales of water allocations were AU$ 78 million nationally during 2011–12 (National Water Commission, 2013b, p. 42).

Prices for traded water rights differ depending on the type of traded water rights, trading regions, reliability classes of water access entitlements, and time of the trade.

As illustrated in Table 2, the average price for high reliability water access entitlements was almost twice as high as for low reliability water access entitlements. Price differences are highest in regions that are not connected to other regions (e. g. via a river) (National Water Commission, 2010c, p. 30 f.).

The average price for high reliability water access entitlements increased by 20 % from 2007–08 to 2009–10 to AU$ 2,100/ML but have fallen to AU$ 1,750/ML in 2011–12.

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[43] Net exporter: exports of water rights exceed imports; net importer: water right imports exceed exports.

Table 2: Average water right trading prices in the MDB from 2007–08 to 2011–12 (in AU$/ML)

Water year	2007–08	2008–09	2009–10	2010–11	2011–12
High reliability water access entitlement rights	1,750	~ 2,000	2,100	1,900	1,750
Low reliability water access entitlement rights	NA	~ 1,000	1,250	1,010	1,030
Water allocation rights	650	350	150	32	17

Source: National Water Commission, 2010c, pp. 30-33 and National Water Commission, 2013b, pp. 36-41.

The average water trading price of AU$ 1,750/ML for high security entitlements in 2007–08 (which was a very dry year with a traded volume of 770 GL) was identical to 2011–12 (which was a wet year with a traded volume of 1,219 GL). Hence, the price of traded water access entitlements does not reflect seasonal fluctuations of water availability or the volume of traded water entitlements. This might be explained by long-term climate change expectations of water users and governmental interaction[44] on the trading market (see Subsection 4.2).

In contrast, prices of water allocation rights had its peak in 2007–08 when the drought was most severe. With increasing precipitation and easing of the drought, the price for water allocation rights decreased by more than 97 % by 2011–12 while the volume of traded water allocation rights increased by more than 200 %. This indicates that many water right holders sold their water allocation rights as a result of water abundance. With increasing volume of water allocation right trades, market prices of water allocation rights decreased. Hence, the market price of water allocation rights does reflect water availability which can be seen as an indicator for a functioning water (allocation right) market.

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[44] In 2010–11 and 2011–12 entitlements bought from the Australian government for restoring issues decreased in comparison to 2008–09 and 2009–10 (see Figure 11). According, total traded volume of entitlements and the market price decreased in 2010–11 and 2011–12 regarding developments of 2008–09 and 2009–10.

3.3.2.2 Trading Barriers and Difficulties

Trades of water access entitlement out of an irrigation district are often volumetrically limited. For instance, in New South Wales and Victoria there is a limit that annually only 4 % of the total volume of traded water access entitlements may be exported out of an irrigation region. Once this limit is reached, trades from this region will be rejected until the end of the water year. In 2007–08, the Victorian 4 % limit was estimated to cause a welfare loss of AU$ 1.5 million due to the denial of a volume of 7.3 GL of water entitlement trades. (Frontier Economics, 2009, p. iv f.).

Trading barriers cause several economic inefficiencies. Allocative inefficiency occurs when water prices for water access entitlements do not equal marginal costs, which is the case when higher valued water users are excluded from buying water access entitlements. Additionally, dynamic inefficiency may occur by misleading long-term water-related decision making. (ibid). Since the trade of water access entitlements is limited, confident long-term decisions including investments and risk management cannot be made by potential buyers and sellers, which lead to subdued innovation and investments into for example new irrigation technology. Productive inefficiency occurs when input factors are not used efficiently. When irrigation farmers are not able to sell water to interested cross-border buyers and cannot gain additional profit from those water trades, they might use the water themselves for less water efficient uses. In those cases the input factor water is inefficiently used and therefore wasted.

In addition to the 4 % limit, in some states trade is only permitted if the net effect of trade is zero. In most cases it will not be possible to trade downstream if the equivalent amount was not previously traded upstream. This bottlenecks system (Murray-Darling Basin Commission, 2006a) is supposed to prevent too much water available in an upstream region and a trade that causes environmental problems in a downstream region. These inter-regional trading limitations could prevent efficiency improving re-allocation mechanisms, which then also hinder a long-term equilibrium on the water market (Shi, 2006, p. 232 ; Brooks and Harris, 2008, p. 398).

Furthermore, when water access entitlements are sold to a water user outside an irrigation district, infrastructure operators[45] charge an exit fee of AU$ 870/ML (2006) maximum depending on infrastructural operators and the reliability class of traded water access entitlements. Some exit fees are as high as 80 % of the value of the traded water access entitlements. This might be one reason why inter-state trade is relatively rare. (ACCC, 2006, p. 45 f.). For trading water allocations, no exit fees are applied and transaction costs are much lower than for traded water access entitlements with a market value of approximately 2–3 % (Grafton et al., 2009, p. 14).

The Australian government participates in the market to buy water access entitlements from willing sellers by the RtB program as already mentioned earlier. This could be problematic in terms of neutrality and impartiality since the Australian government interferes by setting trading rules and water plans on the one hand and on the other hand participates actively on the trading market by buying water access entitlements.

Water right trades also generate negative externalities, which is a reason for market failure. Khan et al. (2009) clarifies the "…nexus between water trading and groundwater-induced soil salinity in […] the Murray-Darling Basin." (Khan et al., 2009, p. 493). When water rights are traded out of an area that is particularly vulnerable for salinity, the irrigation water is missing and unable to rinse out the salt from the soil when the water table is shallow (ibid.).

Even though the above mentioned reasons are not exhaustive they show that there are many barriers and difficulties, which could hinder the water right trading market to meet the goal of allocating water rights efficiently. Regulatory and trading barriers impede the development of a free trading market and the utilisation of trade benefits. Barriers to a free and working market are the lack of uniformity in terms of water right designation, trading rules, and a lack of cooperation between states and water system districts in the MDB. In this way, the transparency of the water market is limited and transaction costs are high, which can lead to the exclusion of farmers and other water users. An additional lack of transparency occurs because "there are no consolidated and consistent water-trade records for the Basin" (Jiang, 2011, p. 282).

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[45] Victorian infrastructure operators did not charge exit fees in 2006.

The fewer barriers exist, according to Bjornlund (2002), the more active the water right trading market is (Bjornlund, 2002, p. 43). Consequently, information asymmetries and trading barriers should be removed or at least minimised to prevent trading market failures.

3.3.2.3 Effects of Water Right Trading

Despite those existing barriers, trading water rights provide water users with incentives to improve their water use efficiency and enables farmers to sell unused water. With this opportunity, no "use it or lose it" strategy needs to be pursued as is often the case in other countries (Grafton et al., 2009, p. 7). Trading water rights helps to prevent the usage of water in a low-valued way by re-allocating it to its highest value uses (Interviews with S1, S2, S6a-c and FR2) and at the same time allows the seller to gain profit from water trade. This would follow the theory of economic efficiency where "resources should be allocated to the uses that maximise overall benefits to society" (Gawel and Bretschneider, 2011, p. 12). Hence, water right trading enables allocative efficiency when the water price equals marginal costs.

The price for traded water allocations provides information about seasonal water availability and demand on the seasonal water trading market. High prices for water during dry years can be a huge incentive for farmers who cultivate water-intensive annual crops[46] to sell their water rights. Profits from water right trading could actually be higher than profits from water-intensive crop cultivation during dry years. Farmers could use this money for example to invest in new water-efficient irrigation technologies to improve the competitiveness and reduce the risk of losses in times of water scarcity.

During the long-term drought experienced in the MDB in the last decade, horticulturists bought water rights from rice farmers and paid high prices for the additional water to keep their plants alive (Interview with FR2, S1, and S7). Without the possibility to buy sufficient additional water, farmers of perennial crops could lose entire plants during times of water scarcity. Therefore, water right trading enables water users to better adapt to seasonal weather conditions.

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[46] For instance, water low value crops such as rice and cotton.

Weather conditions are difficult to predict and farmers do not only have to decide which kind of crop they want to cultivate, but also when they want to buy, keep, or sell water rights. Since water entitlements have different reliabilities classes, it is not clear how much water farmers with lower reliability classes will actually get. It is also uncertain whether the assigned volume of water is enough to get through the cultivation season without having to pay high prices for water rights on the trading market when water is scarce in the middle of the Australian summer. Making the right decisions seems to be somewhat like a poker game and results in recurring pressure on farmers. This pressure and the financial situation of farmers was so serious during the long-term drought that the Australian government decided to supply despairing farmers in severely affected regions with a mental-health worker to prevent suicides (Kumagai, 2010, p. 40).

From the past experiences of the water trading market in the MDB, several lessons could be learnt. Six lessons are specified in the following:

1. Trade can counteract sustainability.
When water rights are traded and new users use originally unused water (sleeper water access entitlements), then the volume of the actual consumed water resources increases if the announced volume of water allocations is not accordingly decreased. The additional usage of water on the Basin scale (Interview with S6a-c) might be one reason for over-use and the exploitation of water resources especially during the long-term drought from 2001 to 2009 resulting in environmental problems (Interview with S3 and FR2).

Water planning and the water right system was more or less "experimental in nature [… and] have generally not been objectively evaluated" (Hamstead et al., 2008, p. viii). Consequently, governmental failure led to those unsustainable water consumption levels. This failure ought to be corrected by the Australian government by gradually reducing the number of available water access entitlements within the scope of the RtB program in order to achieve sustainable water allocation schemes.

Hence, when water rights get tradable, it is important to take into account the whole *resource system* (e. g. the whole river basin) in the water planning process and not just managing single *resource units* without acknowledging neighbouring water consumption patterns.

2. Barriers impede free water right trading.

In Australia, water right trading activities have been modest in the past. High exit fees and for example the 4 % limit constrained trading so strongly that there was barely no inter-state water access entitlement trading during the past few years. Some of the barriers are reasonable in order to prevent over-exploitation of water resources in some regions but they also limit the applicability of a well-functioning trading market and impede allocative, productive, and dynamic efficiency. Hence, a balance between state intervention and free trading markets must be found.

3. More transparency is essential.

It is a big disadvantage when the same types of water rights have different denotations in different states and territories. As soon as those different markets are connected, by enabling users to trade water across borders, higher transaction costs occur (see also Subsection 2.2.1).

Additionally, information systems must be transparent so that every willing seller or buyer of water rights is able to receive information, which is easy to understand, accurate, complete, timely, and unambiguous.

4. The coordination of water extraction from border-crossing water bodies is crucial.

In order to prevent unsustainable water management, which occurred in the MDB because too much water was announced to be extractable (caps) by the Basin state governments without acknowledging neighbouring water consumption, the independent and intergovernmental MDBA was established. All states in the Basin conferred their water planning powers to the MDBA. With this centralisation of water planning, over-consumption of water should be prevented in the future. Consequently, with the establishment of an inter-state institution, not only water planning, rule setting, coordination, and control of water markets, but also an achievement of objectives such as sustainable water management and healthy environmental conditions can be pursued.

5. Farmers need a good deal of skill and a cool head.

Trading water rights is a very complex process where farmers have to make decisions that go beyond farming. They need to have an overview of trading rules, laws, and operational procedures (which vary in different irrigating districts and states). They need to balance opportunities and risks carefully, they have to consider limits and be aware of hazards when deciding whether to buy or to sell water rights. As a consequence, farmers and other water users need to develop a wide range of skills and competences, as well as strategic foresight, to be able to participate successfully on the water-right trading market.

6. Short-term responses are possible.
Water users are better able to respond to unpredictable droughts due to the opportunity to buy or sell water rights. This flexibility is a chance for farmers to “survive” seasonal water variability, which could become even more severe if climate change results in longer water shortages and more weather variability.

3.3.2.4 Experts’ Opinions about Water Right Trading

The above mentioned missing cooperation between Basin states and barriers of water right trading do have reasons and pursue certain objectives.

Experts stated that the state governments of upstream Basin states are not as keen on inter-regional water right trades as the Commonwealth government or the South Australian governments. The reason is that those state governments focus on regional development objectives. They “are not that interested in the overall efficiency of water use”. (Interview with S6a-c).

State governments are aware that in many cases the employment and the basis for economic development are dependent on irrigated agriculture, which would get lost when water rights are traded to other regions. For this reason, the Basin states tried to get around reform agenda. “Victoria [for instance] split the water regions up into many more regions than they actually need for water planning and restrictions to trade in other regions because the more regions you have, the more often you are going to hit the out of scheme trade cap.” (Interview with S6a-c).

Since all Basin states signed the Intergovernmental Agreement in 2008, the MDBA takes over water management and concentrates on a river basin level. With this reform, target conflicts of Basin states (which lead to unsustainable water consumption since state governments decided to primarily support irrigation industry at the expense of the environment) are eliminated.

Furthermore, experts raise concerns about negative externalities which arise by downstream trades. Every downstream trade changes the amount of water that is running down the river. In times of high temperatures, evaporation is very intense. Therefore, the volume that is sent down a river does not necessarily reach destination extractors. The consequence is that downstream, an unsustainable amount of water is consumed, which results in negative externalities. This has effects on others that are not involved in the market and the environment. To minimise negative effects caused by water right trading, states might want to be "banning trades, because of the externalities". (Interview with 6a-c). This situation indicates that evaporation and water losses must be included as good as possible when state governments define water extraction levels (ibid.).

The above mentioned non-exhaustive list of lessons learnt from the Australian water right trading experiences and experts' opinions show how complex and difficult the development of a well-functioning water-right trading market is and that a lot of challenges have to be faced if this concept is going to be applied to other regions in the world.

3.3.2.5 Applicability of the Australian Water Right Trading Market to other Regions

Concerning extreme weather events, soil characteristics, geographical location, and climatic conditions, Australia is a country that has a lot of similarities to countries in the southern hemisphere. Extreme weather events and a huge variability of water availability make it difficult for farmers to adapt. Additionally, exports have to be transported over long distances to reach destination markets. High transport costs make it more difficult to compete against the prices of other exporting countries. Moreover, the soil – similarly, for example to countries in Africa – is unsuitable for agriculture without intensive treatment (e. g. applying fertilizer, irrigation). Most parts of Australia's soils are dry and plane with Entisols, Aridisols, and shifting sand, which is similar to North Africa (US Department of Agriculture, Natural Resources Conservation Service, 2005) where agriculture is far too costly and difficult.

Despite these disadvantages, Australia is a big producer of agricultural products of which much is exported.

These circumstances are similar to other countries in the world but this does not mean that water right trading is equally applicable everywhere. Since Australia has a stable political system with sound institutions, good education, and a good financial position, investments in high technology and research help to compensate the above-mentioned disadvantages. Additionally, water rights and water right trading can only fulfil its functions (see Subsection 3.3.2) when systems are stable and users can trust in its persistency since this is the basic condition for developing and investing in long lasting water conserving systems (Solanes, 2001, p. 264 f.).

Farmers who are able to trade water rights can better adapt to changing weather conditions, which is essential for agricultural production. During drought periods, the trading price for seasonal water rights increased and many Australian farmers were in serious financial difficulties. But governmental initiatives supported farmers who had huge losses and financial troubles.

Countries without such social systems and opportunities to support farmers during droughts might refuse basic needs satisfaction in cases of autarkic farmers by introducing a water right trading regime, which re-allocates water to those who have the financial capabilities to pay higher water prices. This could cause hunger, malnutrition, or even death for those who do not receive help.

Hence, the applicability of the Australian system of water right trading to other regions in the world depends to a large extent on contextual factors such as financial support during extreme situations or the support of farmers to find other employment options in different sectors if farming is not economically viable.

In the case of the Australian MDB, water allocation has to be coordinated only within one single country. In many other cases, river basins extend across different countries, which may not be willing to coordinate water extraction levels with neighbouring countries. Consequently, to achieve sustainable extraction levels and to establish a working water trading market, it is important to coordinate water extraction on a basin scale as the experience of Australia showed.

The institutional arrangements, stability of political systems, good education and financial position, structure of industry, as well as the existence of a solid social system determine the success or failure of management strategies. It has to be considered carefully whether the Australian water right trading system should be applied to other countries and which social, ecological, and economic consequences this would have.

3.3.2.6 Conclusion to Water Right Trading

Water right trading in Australia is a market-based way to coordinate supply and demand for water rights. In Australia, water rights started to be traded in the mid-1990s. The establishment of a market on which water rights can be traded seemed to be very promising. Major advantages are the possibility to re-allocate water to its highest valued uses and the increase of flexibility of farmers, which enables them to manage water supply uncertainties (Shi, 2006, p. 230).

Contrary to those advantages, the water right trading market in the MDB is incomplete and causes high transaction costs. Due to the possibility to trade water rights, "sleeper entitlements" were activated and overall water consumption rose. As the result of missing inter-state coordination in the water planning process and the announcement of too much water being extractable, water was over-consumed in the MDB.

The establishment of an institution that coordinates and controls the water right market with an improvement of allocative efficiency is essential. A sustainable use of water is only possible if the available amount of water rights is specified and adjusted to seasonal conditions. Hence, a sustainable amount of available water rights must be achieved by improving water planning on a Basin scale (Subsection 4.1.1). Then, water right trading is a promising solution for Australian farmers to better adapt to weather variability and to use water sustainably.

3.3.3 Determination of Rural Water Prices

Ideally, the water price mirrors the level of scarcity, its economic value as a natural resource and its opportunity costs. Additionally to this scarcity-related price constellation, the water price should cover costs, which may occur due to water service provision that includes storage, delivery, and treatment. (Solanes, 2001, p. 262).

In the case of rural water prices in the MDB, it is necessary to differentiate between charges for water extraction from regulated water system, which apply for

1. water rights on the water right trading market and
2. water delivery and usage (including fixed prices for water rights)

and charges for private diverters which are users connected to unregulated water systems.

Prices on water right trading markets

The price for water rights on the trading market should reflect demand and supply of water rights. It was observed that the price for water allocations increased when water was scarce during drought periods. Therefore, the water allocation trading price reflected water scarcity and the relationship between demand and supply. Experts assess water prices on water allocation trading markets fluctuating enormously through the season and between different valleys in the MDB (Interviews with FR1a, FR1b and FR2). “Nothing varies as much in price and quantity as water.” (Interview with S8). On temporary water right trading markets, water prices varied between AU$ 20/ML during wet periods and AU$ 1,000/ML in times of drought (Interviews with S1, S2, S6a-c, S7, S8, FR1a and FR1b).

As discussed before, this was not the case for traded water access entitlements. They do not reflect seasonal fluctuations of water availability but long-term expectations of water users as already mentioned before.

Wheeler et al. (2008) mention, that markets for water rights “developed to a high level of maturity” (Wheeler et al., 2008, p. 37). However, trading barriers, a lack of information, and the risk-averse habit of demand concerning water access entitlements (price-inelasticity of demand) are reasons, which make those trading markets incomplete (see Subsection 3.3.2.2).

Prices for water deliveries in regulated water systems

The rural water price structure for water deliveries from regulated water systems, which include planned prices for water rights (in the following called water charges) in the MDB differs from the ideal of covering the economic value of water, its opportunity costs and costs which arise for water provision services. The price is not reflecting the value of water since it is kept consistent and stable (ACCC, 2012, p. xviii) and is meant to cover only the costs, which arise for water related services. The water charges derive from long-term water price plans that include a price determination for typically four to five years (ibid, p. 119 and New South Wales Office of Water, 2009, p. 2). Hence, water charges are not a result of market mechanisms.

Water service providers are not free to determine the charge for water independently. In the MDB, independent institutions are empowered to recommend water prices, rural water infrastructure operators are allowed to charge according to the *Water Charge (Infrastructure) Rules* (ACCC, 2012, p. 31). These independent institutions are the Independent Pricing and Regulatory Tribunal (IPART) in New South Wales, the Queensland Competition Authority in Queensland, Victoria's Essential Services Commission, and the Essential Services Commission South Australia. (ACCC, 2008, p. 12).

Depending on the claimed services, which arise in the course of water delivery processes from regulated water systems, different fees and charges have to be paid to the involved water service providers. Generally, customers' bills vary widely "depending on the irrigation area [… they] are located in, the type of [water access] entitlement they hold, their level of water usage and the type of infrastructure network used by the IIO to provide water delivery services" (ACCC, 2012, p. 47), which may be a gravity flow delivery system or a piped system. If an IIO receives the water from a bulk water operator, it passes the costs directly to its own customers (ibid., p. 44). Hence, an IIO-customer pays the IIO and the bulk water operator for their services.

Since the area of the MDB extends over five states, the charging structures of water service providers vary considerably across the MDB. Tariff structures range from single-part to two-part tariffs (ACCC, 2012, p. 35).

Single-part tariffs apply fixed charges, which occur for provision and maintenance of the irrigation network including the expansion and renewal of the infrastructure systems (ibid, p. 45). These fixed costs arise also during drought periods when water is scarce and cannot be delivered to irrigators as required. In these cases, irrigators pay the price for services without receiving the (full) quantity of water specified by their water right. "That fixed cost has been quite a big burden for many farmers over the drought, because they have had to pay that" (Interview with FR2) although they did not get any water deliveries. For instance, in Victoria, the bulk water operator Goulburn-Murray Water applies the single part tariff with charges differently between locations (which is accompanied by varying requirements to deliver water to irrigators) as well as differently between reliability classes of water rights (ACCC, 2012, p. 36).

Two-part tariffs cover fixed costs and variable costs. Variable costs occur for water delivery as well as for the drainage of water. Variable charges are set for volumetric water use and therefore vary regarding to water deliveries. (ACCC, 2012, p. 45). Variable costs include costs for electricity, which is needed to transport water. Fixed costs mirror supplier's costs that arise independently of the volume of water delivered. For instance, two-part tariffs are applied in New South Wales by the water service provider State Water. Here fixed charges are differentiated by reliability classes of water rights and location. Variable charges are separated according to local requirements. Queensland's bulk water operator SunWater applies the two-part tariff system with a location-based differentiation of charges. (ibid., p. 36).

Taking these structural differences into consideration, independent institutions determine cost coverage of water service providers by defining the prices these operators are allowed to charge, which limits their possible revenue. Since water availability is limited during drought periods, revenue from volumetric tariff systems would be minimal and profit negative if costs were simply covered by these kinds of revenue. This risk of revenue should be considered in the price determining process (ACCC, 2012, p. 38).

Due to high uncertainties regarding weather extremes and a wide range of water availability, water demand and water supply vary tremendously in the MDB. In the price determination process, the independent institutions use specific approaches to forecast bulk water extractions to reduce the risk of under-covering of costs due to less sales of water in dry years (IPART, 2010, p. 118). The more precisely these forecasted extractions match real water extractions, the better suppliers' costs can be covered by water sales. Future long range forecasting is expected to be much better (Interview with S8), which is important if water pricing is planned and not a result of market forces. Despite efforts in the developments of different approaches, the accuracy of weather forecasting is limited and may lead to market failure when information is not complete.

In the last years, water charges increased in most parts of the MDB. “One possible reason for increasing charges was to compensate for under-recovery of costs during the drought.” (ACCC, 2012, p. xix). The Council of Australian Government water pricing reform from 1994 included “the principles of consumption based pricing and full-cost recovery, elimination of cross subsidies and making subsidies transparent.” (Tisdell et al., 2002, p. 27). As observed in the past, the full-cost recovery is mainly still not realised (especially not during drought) and was balanced by (cross-) subsidies and governmental compensations (Essential Services Commission of South Australia, 2012, p. 43; Tisdell et al., 2002, p. 1). Schoengold (2006) stated that “the price of water delivered to farmers is so highly subsidised that there is no significant demand response to modest price changes” (Schoengold et al., 2006, p. 1).

Proof that irrigation water is highly subsidised can be observed in the example of Queensland. The water service provider SunWater distributed the biggest share of its water to irrigators with 77 % of total water deliveries (16 % industrial, 7 % urban). On the contrary irrigators’ share of revenue was just 28 % (64 % industrial, 8 % urban). (SunWater Limited, 2012, p. 2). Already included in the 28 % are payments from the Queensland government called community service obligation (CSO) that are “provided for schemes (or scheme segments) that were unable to recover […] costs” (ibid., p. 3). “Where prices do not provide sufficient revenue to SunWater […], Government has provided CSOs” (SunWater Limited, 2012, p. 461). SunWater stated furthermore: “Under a 70 % Part A (fixed) and 30 % Part B (variable) tariff arrangement, 30 % of SunWater’s revenues [derived from farmers] are potentially at risk. In the case of zero water use, SunWater would recover only 70 % of its revenues [from farmers]“ (SunWater, 2006, p. 13).

In this case, the main customers (which are irrigating farmers) do not pay nearly as much as it would be reasonable regarding the volume of water consumed (77 % share of water deliveries vs. 28 % share of revenues). In fact, water charges for irrigators often do not even cover costs that occur for water services (such as storage, drainage, delivery) nor do they reflect the true value of the natural resource and its scarcity (including opportunity costs).

If providers' costs cannot be covered by water sales, water providers become dependent on governmental subsidies. For instance, the Independent Pricing and Regulatory Tribunal of New South Wales (IPART) refers to a share of costs of the New South Wales' water service provider State Water to be covered by water users as well as the government. Water users' share covered 68.6 % of the total costs of State Water in 2009–10. The remaining 31.4 % was covered by the New South Wales government. (IPART, 2010, p. 7).

Besides the risk of water scarcity and resulting income losses, a reason for problems of cost recovery is the low water charges. By increasing those water prices, the problem could be solved. The total irrigation expenditures of irrigating farmers do not represent a large share of total farm costs since irrigation expenditures range from between approximately 2 % on farms that use drip irrigation and cultivate less irrigation water dependent crops such as fruit and vegetables and maximum to approximately 17 % on farms that cultivate very water intensive crops such as rice (Ashton 2012; see Subsection 3.3.3.1). The lower the share of costs for water to total costs, the less reactive is demand on water price changes and the less incentives exist for water efficient usage.

Water prices do have the potential to increase and cover the costs of the suppliers. However, in some regions the cost share of water is significantly increasing: "For example, bills as a percentage of total farm costs […] increase from 3.49 % in 2006–07 to 10.4 % in 2013–14" (IPART, 2010, p. 176) in the Macquarie valley.

To be able to cover costs from water sales it is not only important to increase the water price but also to reduce costs of water service providers. Since a monopolies' incentive to do so is quite small, external control or regulation would be necessary. This is done in the MDB. The independent institutions often advise water service providers to reduce costs for the next planned period since monopolies are not as efficient as companies under competition (IPART, 2010, p. 75). Although water service providers show the willingness to reduce costs (IPART, 2010, p. 77), external independent control can help to turn commitments from monopolists into reality.

Prices for private diverters of unregulated water systems

As already pointed out, unregulated private diverters mainly occur in northern MDB.

In New South Wales, charges for unregulated water extractions are paid to the New South Wales Government, Department of Primary Industries, Office of Water (in the following called New South Wales Office of Water) (IPART, 2012, p. 4) which plans, manages and protects water resources in New South Wales (New South Wales Office of Water, 2013a). IPART sets the maximum prices that the New South Wales Office of Water is allowed to charge for their services (New South Wales Office of Water, 2013b).

Charges for unregulated water systems are generally low (Commonwealth Environmental Water Holder, 2012, p. 40). The cost structure varies between two-part tariffs and single-part tariffs for metered private diverters of unregulated systems. The single-part tariff assumes full license usage, which is meant to be an incentive for unregulated water diverters to install meters. (New South Wales Office of Water, 2013c). Single-part tariffs vary regionally. Water users pay for instance AU$ 5.34/ML in the Peel region and AU$ 11.58/ML in the Murrumbidgee region in 2013–14, which is multiplied by the number of ML or units their license is assigned to. (New South Wales Office of Water, 2013b).

Two-part tariffs also vary regionally. Water users have to pay a fixed charge for the license itself which is for example AU$ 3.73/ML in the Peel region and AU$ 8.30/ML in the Murrumbidgee region in 2013–14. Additionally, the user has to pay a volumetric based charge of AU$ 1.60/ML in the Peel region and AU$ 3.55/ML in the Murrumbidgee region. (ibid.). This two-part tariff is comparable with the pricing system in regulated water systems in which the farmer has to pay the price for the water access entitlement and the price for water deliveries.

None of the pricing systems of unregulated systems aim to reflect water scarcity but to keep water prices stable and cover costs which arise in the water planning, metering, and application processes (New South Wales Office of Water, 2013b).

According to the interviewed experts, water charges irrespective of whether they are regulated or unregulated systems are generally too low. They argue that it is cheaper to acquire water by purchasing it rather than by on-farm infrastructure investments (Interview with 6a-c). However, especially during drought, a lot of farmers called the pricing system unfair because they had to pay the fixed price but were not allocated water. A policy “in quite a few of these areas [… in the MDB] was that the fixed charges got waved, the state government came in and paid for the fixed charges". (Interview with S6a-c). In those cases, the government not only subsidised water suppliers but also took over the water users' cost share of fixed costs which are intended to cover costs for supply and maintenance of infrastructure.

Allocation efficiency cannot be met when water is subsidised by the government and water demand is primarily increased instead of decreased. As a consequence water is over-consumed in the MDB. The intention of the previous water reforms was to decrease water consumption by applying quantitative limits rather than applying water pricing strategies. One of these strategies could be to reduce governmental subsidies with the consequence of a rising water price and a decreasing water demand.

However, a water price increase cannot be an incentive for irrigators to decrease the level of water consumption when the cost share of water to total farming costs is not high enough and therefore water price changes are only slightly noticeable. The relevance of demand elasticities, which describes the change of water consumption as a result of changing water prices, is described in the next subsection.

3.3.3.1 Water Demand Elasticities

The WMP of water pricing is only practical when the policy's goal is reached. In the MDB, the water market is not free and the water price results from water plans. The most important prerequisite for successfully achieving water pricing policies is a clear response of demand to water prices. The price elasticity of demand "is defined as the percentage change in demand in response to a unit change in its price" (Wheeler et al., 2008, p. 41). Hence, water price elasticity of demand implies to be the percentage change in water quantity demanded in response to a 1 % change of the water price.

The water price elasticity of demand in response to the water price is negative in general. However, the range of elasticity is enormous. In OECD countries, water price elasticity ranged from -0.05 to -17.7 (Franco-Dixon et al., 2007, p. 31 f.). More precisely, a study by Schoengold (2006) found that the water price elasticity of agricultural demand is -0.79 in the north of Los Angeles (Schoengold et al., 2006,

p. 1). Based on the trading market price, Wheeler et al. (2008) found the water price elasticity of demand ranged between –1.51 and –1.99 in the Murray River region (Wheeler et al., 2008, p. 50) and –0.02 and –2.81 in the whole of Australia (Wheeler et al., 2008, p. 42 f.).

Water is an essential input factor for irrigation farming. Since water cannot be replaced by other inputs, it has no substitute. If rainfall is insufficient, and on-farm storages are depleted, crop output will decrease if no additional irrigation water is used. Demand elasticity is therefore not dependent on complements or other inputs.

However, the water price elasticity of demand depends on several factors that have an influence on the responsiveness of irrigators as exemplified in the following.

The initial water price is one of the most important influencing factors. Appels et al. (2004) found that at low water prices (below AU$ 50/ML), irrigation water demand is relatively inelastic[47]. Water demand becomes more elastic at higher prices. (Appels et al., 2004, p. 8 ; Wheeler et al., 2008). If the water price increases by 10 % from AU$ 50/ML to AU$ 55/ML for instance, this would have a minor influence on water demand. However, when the initial water price is very high for example AU$ 1,000/ML, a 10 % increase in the water price to AU$ 1,100/ML would result in noticeable demand decreases. Hence, higher water prices induce elastic water demand.

The responsiveness of water demand to water prices also depends on the share of costs paid for water to total costs (Appels et al., 2004, p. 30). If the cost share of water is relatively small, water price increases would have minor impacts on water demand since production costs do not perceptibly increase in total. The cost share of irrigation water to total costs was estimated by Hajkowicz and Young to be 16 % for rice production, 4 % for cotton, 3 % for grapes, 2 % for vegetables and 1 % for fruits. They state that the profitability of crops where the cost share is higher than 15 % is more sensitive to water price changes and crops whereas if the cost share is lower than 5 %, it is less sensitive. (Hajkowicz and Young, 2002,

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[47] "Between zero and –1, demand is said to be relatively inelastic. That is, the quantity demanded, responds by less than the proportionate change in price. In such a case, farmers' expenditure on water will increase in response to an increase in price even though their consumption of water has fallen." (Appels et al., 2004, p. 8).

p. 13). Interviewed experts felt the water costs were small, in relation to overall expenditures in the areas of horticulture but were quite high for annual crops such as rice in the MDB (Interviews with F2, FR1a and FR1b).

This confirms the data from ABARE's farm survey stating that the cost share of irrigation water varies quite significantly between several crop types and seasons. Rice farmers' cost share of water ranges between 3 % in times of drought (since rice is not cultivated in times of drought) and 13 % in wet years, between 4 % and 2 % for cotton farmers (slightly decreasing over time[48]), between 4 % (wet year) and 17 % (dry year) for grape farmers, 6 % and 2 % for vegetables (decreasing over time), and between 3 % (wet year) and 11 % (in times of drought) for fruit. (see Appendix 7.5). (Ashton, 2012).

Consequently, the higher the share of water costs to total costs are, the more elastic water demand gets according to water price changes.

In addition to these factors, weather conditions, soil characteristics, and the geographic location are decisive for the response of demand to water prices.

Conditions influencing the demand for irrigation water include rainfall and temperature. In dry years, the absence of rain must be compensated by crop irrigation. Higher temperatures entail higher water need of plants. Under these weather conditions, demand for irrigation water is higher (than in cool, wet years) with lower elasticities of water demand.

In conjunction with weather conditions, soil characteristics are decisive for water demand elasticities. The potential to be a water reservoir and the nutrient composition of the soil (regarding density of plants and plant sizes) indicate how much more water, in addition to rainwater, must be applied depending on the requirements of the cultivated plants. The better soil is able to store water, the more elastic is the demand for irrigation water and the less dependent is the farmer on irrigation water.

Moreover, the geographic location and the surface consistency are influencing factors of elasticity of water demand. For instance, it makes a difference if the crop field is located close to a river where lower water transportation costs apply, compared to if it is situated far from a body of water. Furthermore, it makes a

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[48] Observed years of the survey: from 2006–07 until 2010–11.

difference if the crop field is positioned in a sink or on a slope where rainwater is available or if the field is located behind a mountain where rainfall is less likely. Water demand will be more inelastic when conditions for agricultural production are more adverse.

The dependency on irrigation water and therefore also farmers' elasticity of demand for irrigation water must be differentiated between agricultural plant species. Grape stocks and fruit trees, for example are perennialsand therefore more dependent on irrigation water to keep them alive during droughts making them more inelastic than other plant species. Farmers of perennial crops are less flexible concerning cultivating less water intensive crops during drought since perennials are cultivated over a longer period of time (which includes wetter and dryer periods). These farmers cannot choose a more drought resistant plant by crop rotation so as to be less dependent on irrigation water (prices).

The flexibility to change crops, dependent on the weather conditions and the ability for crop rotation have a strong influence on the elasticity of water demand.

Agricultural plant species have different needs for water. For instance, the volume of irrigation water applied for the production of one tonne of crop in the MDB varies between types of crops; for rice it is 1.49 ML/t, for cotton 1.29 ML/t, for grapes 0.32 ML/t, for vegetables 0.14 ML/t and for fruits 0.53 ML/t (ABARES, 2011; FAOSTAT, 2010b; Australian Bureau of Statistics, 2010c) (see Subsection 5.1.4). Consequently, rice farmers need almost three-times as much water to produce one tonne of crop compared to fruit farmers. Thus, farmers' water demand will be more elastic when cultivating water low value crops[49]. On the other hand, demand of high value crop farmers will be more inelastic since the share of costs for water to total costs is lower than the share of low value crop farmers. Therefore, water price increases will not affect water high value crop farmers' profit as intensively. Besides differences between kinds of crops, the demand elasticity for water also differs regarding the age of perennial plants as Qureshi et al. (2010) found: "Along with vegetables, the willingness to pay [for irrigation water] by a newly established grapes farmer […] is the highest, followed by almonds and citrus." (Qureshi et al., 2010, p. 109). The willingness to

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[49] For definition of water high and water low value users and categorisation of crops see footnote 41.

pay for older stocks with less output will be smaller. During drought, farmers most likely only irrigate plants, which have the highest yield and are therefore most valuable to the farmer. Consequently, farmers with less productive plants are more water price elastic.

Another relevant factor for the elasticity of water demand is the potential of technological change. For instance, farmers could change their watering methods by replacing flood watering by drip technology or the like. Farmers with higher potential to improve technology are supposed to react stronger to water price increases than farmers who exploit maximum potential of technological change and cannot reduce water demand by for example improving water efficiency.

Finally, the access to different water sources is an influencing factor for water demand elasticity. By desalination, recycling of water, and rainwater harvesting (which goes along with the capacity of on-farm water storages) water supply and sources for irrigation water is enlarged. Farmers with such opportunities will be less sensitive to water price increases. Different water sources enable farmers to choose the cheapest one. Water demand would be more elastic in these cases. Farmers' demand is more inelastic when different water sources are not available. The same applies for the accessibility to different water pools due to ownership of diverse water rights. In drought periods, farmers with surface and groundwater water rights can choose the cheapest water source and reduce the water use of the more expensive water source as much as possible. Therefore they have a more elastic water demand than farmers with just surface water rights.

Depending on all of these factors, price elasticity of water demand differs strongly between irrigators. Therefore, water demand management policies of water pricing should take these factors into account. In cases of higher elasticity, a water price increase would lead to a reduction of water consumption and thereby water pricing can be a good instrument to successfully change water demand.

3.3.3.2 Subsidies of Water Suppliers

Conflicting policy goals are obstacles to the success of water pricing. On the one hand, this can be explained by the fact that governments subsidise water to make it more affordable to irrigators to boost the agricultural economy in the MDB. On the other hand, unsustainable over-consumption of water should be stopped by applying WMPs. Conflicting targets must be considered and balanced. The governments must be aware of consequences of policy measures. Therefore, goals must be clearly formulated and impacts of governmental interventions should be evaluated in a holistic way.

Subsidising water prices is in conflict with the objective to reduce demand. As explained above, water is highly subsidised in the MDB. Although the Australian water reform from 1994 initiated that irrigators are responsible for all occurring costs by 2001 (Garrido, 2002, p. 7 f.), this goal is still not accomplished. Water suppliers' costs are not completely covered by revenues arising from sales of irrigation water.

The example of New South Wales

In New South Wales, the water service provider State Water Corporation has the monopoly position with an average water delivery capacity of 4,600 GL annually for approximately 6,300 customers and 14 regulated river systems. For water pricing the Independent Pricing and Regulatory Tribunal (IPART) is responsible and formulated the goal that revenues from water sales should cover costs of the water provider. (State Water Corporation, 2012, p. 5).

Data from State Water's annual reports from 2004–05 to 2011–12 illustrate that the development of operating expenses are somewhat connected to the volume of water deliveries. For instance, in 2007–08, water delivery was about one quarter of the water deliveries in 2005–06 as shown in Figure 6. Despite the fact that far less water was delivered to water users, total expenses did not decrease to the same extent (about 7 %) from AU$ 71,561,000 in 2005–06 to AU$ 66,833,000 in 2007–08. (ibid.). Consequently, fixed costs that are independent of the volume of water deliveries, are relatively high.

Figure 6 shows the gap between revenue from water sales (here called revenue from water deliveries) and total expenses. The goal of the State Water Corporation is to price water so that costs are covered (State Water Corporation, 2012, p. 5). However, costs are just covered when revenues from governmental grants and subsidies, revenues from the MDBA due to contract works and other utilities, interest and other revenues are included in the calculations (ibid., p. 9). In this example, revenues from water deliveries have to be more or less doubled in order to cover the costs in the event other revenues, grants, and subsidies were reduced to zero.

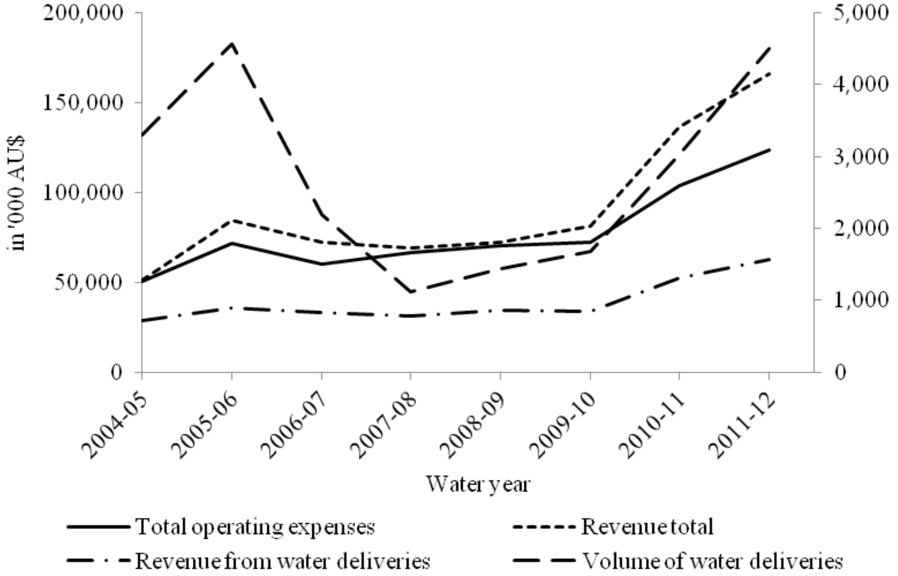

Figure 6: *State Water Corporation's expenses, revenue and water deliveries (own illustration, data from State Water Corporation's annual reports 2004–05 to 2011–12).*

By dividing State Water's total expenses by the volume of water deliveries, it is possible to find an appropriate water price that reflects full-cost recovery by considering the volume of water sales. Without allowing any profit margin, this simple calculation illustrates (in Table 3) that the water price per sold ML must be higher during droughts to cover costs since less water is sold due to a decreasing volume of available water.

In 2007–08 when the drought peaked, total expenses for the service provider State Water were AU$ 66,833,000. By dividing total expenses by the volume of water deliveries of 1,125 GL in 2007–08, a water price of AU$ 59/ML arises, which would cover total operating expenses by revenues from water deliveries.

Table 3: State Water Corporation's expenses and water deliveries

Water year	Total operating expenses in '000 AU$	Volume of water deliveries in '000 ML	Total expenses divided by volume of water deliveries in AU$/ML
2004–05	50,377	3,308	15
2005–06	71,561	4,575	16
2006–07	60,443	2,200	27
2007–08	66,833	1,125	59
2008–09	70,410	1,446	49
2009–10	72,163	1,680	43
2010–11	103,917	3,031	34
2011–12	124,056	4,500	28

Source: State Water Corporation's annual reports 2004–05 to 2011–12.

To compare the data of regions within the MDB, in 2007–08 the Peel region had the highest regulated river water prices at a level of AU$ 11.51/ML for high security, AU$ 3.38 for general security, and AU$ 17.45/ML for usage. In the same water year the highest prices in the Murrumbidgee region for regulated river water were AU$ 2.87/ML for high security, AU$ 2.31/ML for general security, and AU$ 2.18/ML for usage. (State Water Corporation, 2008, p. 46). That means that a farmer for instance with a 1,000 ML general security water access entitlement who used 500 ML in the water year 2007–08 paid (AU$ 3.38*1,000) + (17.45*500) = AU$ 12,105 in the Peel region whereas the farmer in the Murrumbidgee region payed (AU$ 2.31*1,000) + (AU$ 2.18*500) = AU$ 3,400 for water consumption holding exactly the same water right and consuming the same volume of water.

That example shows the large water price differences between regions, which arise due to "differences in charge amounts [that] are in partly driven by differences in underlying costs associated with the physical characteristics of irrigation networks, including the costs of investment, operation, and maintenance faced by IIOs" (ACCC, 2012, p. 49).

To gain cost recovery by water sales, the water price would have to increase in the future. However, as Table 3 shows, State Water's expenses increased over time (which may be caused by the inflation rate and an increase in maintenance costs for repairs of old networks) independent of water availability and water deliveries (which are much less during droughts). Therefore, the share of fixed expenses is relatively high and actually delivered water is of little importance.

Since the water price does not cover these costs adequately, revenue from governmental grants and subsidies had to be increased from AU$ 10,495,000 in 2004–05 to AU$ 44,277,000 in 2011–12 (State Water Corporation, 2012; State Water Corporation, 2005). The consequence is that the gap between total revenue and revenue from water storage and deliveries tends to increase instead of decrease (see Figure 6) since revenues from water storage and deliveries do not rise at the same rate.

This subsidy system still seems to be taken for granted by water pricing institutions, which is quite surprising since IPART, which is responsible for determining the water prices in New South Wales, assume the governments' share of cost recovery to increase from a cost-share level of 31.4 % in 2009–10 to 43 % in 2013–14 (and users' costs share decreases from 68.6 % in 2009–10 to 57 % in 2013–14) (IPART, 2010, p. 7). From an economic point of view this is a deterioration regarding the goal to decrease water consumption and over-allocation and to develop incentives for water savings and a sustainable level of water consumption.

Those explanations show that market prices for water deliveries are currently not able to cover suppliers' costs. This may be an indicator for policy failures and inadequate water planning schemes, which need to be corrected.

3.4 Interventions in the Water Markets of the Murray-Darling Basin

As already mentioned, there is a difference between the market for traded water rights and the market for water deliveries. On both markets, governments are highly involved by regulating or actively taking part. This makes it difficult to find reasons for market failures.

In the following, cases of market interventions are analysed separately, for the market of water rights and water deliveries.

Market for water rights

Water plans, trading rules, and legislation constitute the framework in which the trading of water rights takes place (see Subsection 4.2). Governments initiated many trading barriers (see Subsection 3.3.2.2) and frequently decide how much water is delivered to each water right holder. Despite those governmental interventions, the market mechanisms for seasonal water right trading are more or less functioning. When water is scarce, the water price for water allocations is high and when there is more water available the price is appropriately lower. However, seasonal differences in water availability and therefore the volume of water supply are not reflected by the price of water access entitlements. Even in times when water is abundant, the price for traded water access entitlements is at the same level as during droughts (see Table 2). The reason for this is that farmers "protect their long-term investments in permanent planting and other capital investments such as dairy equipment and cattle" (Bjornlund and Rossini, 2006, p. 2) and that they prepare for the next drought or adapt to climate change by holding water access entitlements so as to be able to receive water. Since the average market price of water access entitlements is more or less stable independent of actual water availability, the incentive for speculators to sell water access entitlements during droughts and buy them during water abundant times is less. Some states even prevent speculation by only allowing land-holders that are able to demonstrate a use for water (National Water Commission, 2010c) to buy water access entitlements. In other states non-landholders are also able to buy and sell water rights by market participation. However, cases of speculation that have a serious impact on farmers are unknown since "no records are kept specifically on speculators" (Power, 2011).

The Australian government actively participates in the water market to buy water access entitlements from willing sellers by the RtB program (see Subsection 4.2). This governmental intervention in the water right trading market must be seen critically since the governments also introduced the legal framework and defined water plans. Besides the problem of the partiality of the governments in the process of legislation, the price paid by the Australian government exceeds the market price for traded water access entitlements, which may lead to market failure because supply and demand cannot be balanced on the water market.

Market for water deliveries

The water deliveries market is not free, therefore the market price is not the equilibrium price resulting from demand and supply forces in the MDB.

Water suppliers in the MDB are primarily state-owned monopolies. Each region has its own monopolist since water users receive water from one bulk water supplier or one IIO as mentioned in the subsection before. But in contrast to other monopolies, those water suppliers cannot use their monopolistic market power to determine the market water price. According to water plans, this price is predefined by the independent institutions. The price users have to pay, for the provision of water, does not fully cover supplier's costs the majority of the time (see Subsection 5.1.8.1). To compensate financial gaps, the governments highly subsidise water suppliers by payments for infrastructural maintenance and financial grants. Therefore, incentives to stimulate innovation, cost minimisation and productivity increases are lacking.

Further interventions

Over-consumption causes external effects and environmental damages in the form of "dryland salinity, acid soils and a number of invasive weeds and pests" (Adamson et al., 2007, p. 263). This pollution of water and soils negatively impacts other water and soil users by limiting the usability of these resources. "The salinity levels, resulting from the decisions of upstream water users, affect crop yields for downstream irrigators" (Adamson et al., 2007, p. 268) in the MDB. Costs for water desalination by technological progresses and the treatment of soils by for example letting fields lay fallow or methods such as "perennial revegetation for salinity control" (Khan et al., 2009, p. 494) are very high and must often be covered by directly affected individuals that are not responsible for those external costs or by the whole society.

In the case of the MDB, it is difficult to apply the polluter-pays-principle since the whole irrigating farm industry would have to be made responsible for over-consumption of water and the resulting salination problems. However, since farmers only used the volumes of water they were allowed to use, the state governments initiated a situation of over-allocation of water rights. This led to over-consumption of water because predefined water prices were too low. Hence, over-consumption of water is a result of incorrect water planning, false water rights provision schemes and inadequate water pricing that represent cases of governmental failure. To remove damages caused by over-consumption, several salinity strategies and action plans were funded by the Basin states and the Commonwealth (Pannell and Roberts, 2010, p. 438). Additionally, a new water reform takes place by introducing the Basin plan that should prevent over-consumption of water.

The Basin states signed the Intergovernmental Agreement in December 2008, which clarifies the Murray-Darling Basin Authority (MDBA) to be responsible for preparing a Basin Plan (see Subsection 4.1.1) that applies to each region in the MDB[50]. Before the MDBA took over responsibility and managed water on a river basin level, each state provided water rights for users of their own district.

In the past, the MDB experienced that water management on a politically defined basis (here the Basin states) is intended to fail when the complexity of river morphology and water demand of neighbouring states is not acknowledged. In this case governmental failure occurs, since governmental water management led to less efficient and less flexible allocations (Petersen, 1993, p. 39) and did not result in market equilibrium[51]. River basins must be managed in an ecologically defined basis (a river basin level), which includes all water consuming regions connected by rivers in a basin.

Furthermore, water is polluted by the usage of pesticides and fertilisers on fields. Those chemicals combined with rainwater enter water bodies with the runoff, whereby the environment and other users are negatively affected. Often, costs for more sustainable practices are higher and the willingness to reduce pollution may be small. It could also be the case that a lack of information about inter-related effects between pollution and environmental damages arises which is another case of market failures. To avoid information deficits, the government could intervene by informational campaigns and knowledge generation to avoid pollution and externalities. This was undertaken for instance within the National Action Plan for Salinity and Water quality when the Australian

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[50] After the already existing water plans expire, which is at the latest in 2019 in the case of Victoria. In all other Basin states recent water plans expire before 2019.

[51] What the mismatches between water supply and water demand shows. During drought, not all water rights could be provided with water. For example in 2007, just 30 – 55 % of high security water access entitlements could be delivered with water in Victoria and South Australia. Low reliability class water access entitlements could mostly not be delivered at all (National Water Commission, 2008a, p. 5).

Commonwealth government funded in total AU$ 44.5 million for the provision of information and R&D (Pannell and Roberts, 2010, p. 440).

3.5 Interim Conclusion

This chapter gives an overview regarding water supply and water demand in the rural MDB. It specifies water market characteristics and procedures of water allocation. Thereby reasons for over-consumption and environmental problems are identified, which justify the need for governmental interventions.

In the MDB, water markets are very complex constructs and many institutions are involved. The market, in which water suppliers are mainly monopolists, is highly regulated by the government. Despite these interventions in the water market, water was over-allocated causing environmental problems especially during droughts.

The main reasons for over-consumption of water and environmental problems are summarised in the following. Some of these reasons are related and may influence each other.

1. Quantity of permanent water rights on the water market
Water access entitlements define the "exclusive access to a share of water from a specified consumptive pool as defined in a water plan." (National Water Commission, 2010b, p. 3). The quantity of these water rights are based on levels established prior to 1994 when water rights were bundled to land. With the possibility of trading water rights, sleeper entitlements were activated and more water was used than before.

As a consequence, general security water access entitlements are rarely fully allocated. High security water access entitlements were only allocated approximately 50 % in times of drought. In cases in which farmers pay for the licence of permanent water rights but do not receive full volume, the market fails. This failure indicates an inappropriate number of existing permanent water rights (defined volume of water rights exceed possibilities of water extraction).

2. Water planning
State governments announce the volume of extractable water (water allocations) seasonally. These announced levels were too high in the past, since Basin states did not take water consumption of neighbouring states into account. This is one reason for over-consumption of water in the Basin.

The sum of all water allocations must not exceed limits of maximum water extractions (also called caps) defined in water sharing plans. Those plans are long-term, which causes the following problem. Water sharing plans and defined caps are not flexible enough to mirror varying water availability. Those changes can be significant since Australia faces recurring severe droughts and devastating floods. Climate change exacerbates the situation of drought, which will be more severe in the future leading to more intensive scarcities. Long term water sharing plans do not take fluctuations of water supply into account. The level of caps orientate on the 1994 level of development that allows rural water users to extract a maximum of 11,500 GL annually in the whole MDB. This volume is far too high especially during droughts and in the past, led to environmental damages.

3. Water pricing
In free markets, when the limits of maximum water extractions are set too high, the water prices are consequently too low. This also leads to the over-consumption of water. This indicates that the volume of extractable water exceeds the sustainable volume. To avoid this, the actual water price has to be higher to mirror water scarcity.

However, as pointed out in this chapter, the water market is not free and the water price is predefined and fixed on a low level. This price is not even able to cover costs of water suppliers, which are highly subsidised for this reason. Additionally, the water price does not include opportunity costs nor internalises externalities. Consequently, no market-based signals for water scarcity were available during droughts so that water was unsustainably used and inefficiently allocated.

4. Lack of information
For seasonal announcements of extractable water, it is essential to know how much water is available in every single consumption-pool (e. g. a river or a dam).

Furthermore, it must be known how much water must remain in that pool to satisfy environmental needs. Additionally, water losses that may arise due to evaporation and transportation losses and measurement inaccuracies must be taken into account when determining the volume of extractable water. This volume then equals the maximum level of sustainable water supply that can vary frequently when considered conditions change. Since most of the above listed information are unknown or lack completeness, the information asymmetry may be one of the reasons that the announced volume of extractable water was not sustainable in the past and led to over-consumption.

5. Focus of political objectives

From a positive point of view (concerning regulation theory), over-consumption is caused by the fact that state governments are strongly influenced by the lobbyism of the irrigation farmers industry and regional political objectives such as the increase of economic development. Therefore, political objectives focused on supporting the agricultural sector. The consequence of this was agricultural land expansions and an intensification of irrigated agriculture. Since the target of regional economic development is in conflict with the target of protecting the environment, pursuing one target is only possible at the expense of the other. In the past, the environment was not in political focus. This leads to the over-consumption of water and environmental damages in the MDB.

Those reasons previously explained, represent a mixture of governmental and market failures. Agricultural production is the largest water consumer in the MDB. After realising what devastating consequences over-consumption of water had for the environment, political targets changed from agriculture supportive policy towards environmental protecting policy. Four existing and potential institutional arrangements (also called water management policies) are introduced in the following chapter. Those policies are aimed to solve the problem of over-consumption, each addressing different approaches as the next chapter illustrates.

4 Water Management Policies in the Murray-Darling Basin

When a misbalance of supply and demand and therefore allocative inefficiencies occur on the water market, WMPs can either have the goal to increase the water supply or to reduce the water demand.

Water supply increasing management policies aim to quantitatively enhance the volume of water that is available for consumers. For instance, this can be realised by desalination, grey water recycling, rainwater harvesting, and infrastructural modifications by for example the establishment of new pipelines or networks to connect uncultivated regions. These supply related possibilities to balance water supply and water demand is however not the focus of this research.

Chapter 3 addressed the reasons for over-consumption of water in the MDB in the past. This chapter provides contextual background regarding recent and potential WMPs, which may be able to solve this problem. Two non-pricing and two pricing policies are investigated, all aimed at solving the problem of over-allocation of water by reducing the water demand.

Non-pricing strategies have the objective to provide incentives for water efficient usage and for water savings without directly regulating the market price of water. This can either be done by applying non-pricing monetary strategies, or non-pricing non-monetary strategies.

Non-pricing monetary strategies provide financial incentives for water savings by offering for instance rebates for the replacement of water-inefficient appliances. One example of this non-pricing monetary strategy is governmental market participation, creating financial incentives to sell water rights to the government that will result in a decrease of available water rights on the water market (RtB program in the MDB, see Subsection 4.2).

Non-pricing non-monetary strategies have the goal to create incentives without using monetary instruments. This could involve the establishment of a law that engages households to use only water saving technologies for showers and toilet flushes, or informational campaigns, and educational programs. Another example of a non-pricing non-monetary instrument would be the introduction of quantitative limits for water usage, which are called caps. By applying for instance water sharing plans (see Subsection 4.1) or urban water restrictions (see Burdack, 2011), these quantitative limits would regulate the amount of available water for human needs.

Water pricing strategies directly regulate the water market price by pursuing certain goals. This could include the creation of incentives for efficiency increases of water usage or reducing demand by predefining the water price to a high level. The higher the water price the bigger the incentive to efficiently use water or abstain from usage by not using it for certain procedures (e. g. surface watering). Other goals include the improvement of allocation efficiency on the water market and consumer protection from market power in cases of natural monopolies (see Subsection 2.2.2). In the last mentioned case, water pricing could have the objective to cover costs of suppliers with the market price but also limiting the monopolist's profit.

In the following, the non-monetary strategy of the water sharing plan (Subsection 4.1) of the Basin that is currently in the developing process, the non-pricing, monetary RtB program (Subsections 4.2), which was introduced as part of the *Water for the Future* program in 2007–08, as well as two potential water pricing policies developed by the author are presented. These two pricing strategies are the full cost recovery – subsidy removing strategy and the environment compensating irrigation tax strategy, which are explained in Subsection 4.3.

On this basis, the WatIM-Model evaluates the impact of those WMPs on irrigated agricultural crop production by applying an economic scenario analyses in Chapter 5.

4.1 Water Sharing Plan

Water planning including the assurance of water quality and water supply is seen as the key tool concerning sustainable water usage by managing water allocation and water sharing between conflicting users in the MDB (Hamstead et al., 2008, p. viii). Existing water planning instruments are called water sharing plans in New South Wales and the ACT, bulk water access entitlements in Victoria, water allocation plans in South Australia, and water resource plans in Queensland (Murray-Darling Basin Authority, 2011b). For reasons of simplification this thesis sums up those varying names to the term water sharing plans. One key issue is to regulate water consumption by defining quantitative limits for water extraction that are also called caps. Water sharing plans formulate conditions under which water extraction is possible. Such conditions are for example a minimum river level or flow, or a specific inflow into a water reservoir (e. g. a dam) (Hone et al., 2010, p. 10).

The variety of water sharing plans and their complexity become obvious when considering the number of existing water sharing plans and their differences within the MDB. In 2010, about 190 water sharing plans existed, each following diverse approaches to solve conflicts between competing water users including the environment (McKay, 2011, p. 615). Planning approaches[52] sometimes even vary between regions within the same jurisdiction (Hamstead et al., 2008, p. VIII).

Hamstead et al. (2008) found that water sharing plans for a broader geographic or thematic scope are more general in terms of water and environment management rules, whereas plans for a narrower scope are more specific and precise. They argue that "there is a trend towards detailed plans sitting in a context of broad strategic plans or state-wide 'default' policies and rules." (Hamstead et al., 2008, p. X). In line with the principle of hierarchy of legislation[53], the planning hierarchy of water sharing plans implies that plans on highest levels are superordinated to those on lower levels. Consequently, water sharing plans on state level are superordinated to water sharing plans on a regional level. This hierarchy entails a periodization of political goals, which are formulated in the plans.

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[52] Which costed millions of dollars and have "been experimental in nature" without being evaluated objectively (Hamstead et al., 2008, p. VIII).

[53] In which law of the Commonwealth is in precedence of States and Territories' law.

The goals of water sharing plans are diverse. Some aim to protect ecosystems and water bodies, others manage water use and water sharing divisions. Other purposes include the management of total water systems and to give water users and investors security. (State of New South Wales, Office of Water, 2010, p. 4; Hamstead et al., 2008, p. X).

The aspiration of several goals within different water sharing plans may lead to the following relationships between targets. When the realisation of one goal promotes the achievability of another goal, harmony of goals (complementarity) exists. If the realisation of one goal interferes with the achievability of another goal, they are in conflict (target conflict). With an increasing number of goals, target conflicts increase. They occur mainly when goals are not coordinated, when they are unbundled or when contrary sub-goals exist. (Peters, 1996, p. 123 f.). Since the number of existing water sharing plans in the MDB is so large and goals are so diverse, it is likely that target conflicts will occur.

In the MDB, water sharing plans are valid for 10 to 15 years and are very difficult to change after the State Minister approved the plan (Young, 2010, p. 8 f.). The political reason for such long-term planning is to provide planning security for farmers[54] and water service providers, and to reduce risks. However, in a country of extreme weather conditions as Australia, the goal of providing planning security and risk minimisation is conflicting with sustainable water usage and environmental protection. Long-lasting water plans might not be able to predict water availability in situations of drought and floods. Furthermore, latest scientific knowledge cannot be considered when water sharing plans last for such long periods of time and cannot be updated. Additionally, changing climatic and environmental conditions cannot be included ex post and are difficult to predict ex ante.

Despite those disadvantages, the significance of water sharing plans in the MDB increased. In the last decade, water sharing plans became a key strategy of water management in the MDB and were developed and implemented in many regions where conflicts between water users occurred. Since 2012, all water resources in New South Wales are protected by water sharing plans (State of New South Wales, Office of Water, 2010, p. 4), for instance.

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[54] Which take (financial and cultivating) decisions, which depend on water availability.

Most water sharing plans are designed to protect the environment and help to allocate water in a sustainable manner. As previously mentioned, governments frequently announce how much water will be allocated to water right holders according to the water sharing plans. However, experiences in the past have showed that the volume of available water announced by the government and therefore allocated to users was too high. The consequences were consumption levels which exceeded sustainable extraction levels. Hence, even though governments limited levels of diversion by introducing water sharing plans, water was still over-consumed and managed incorrectly.

Reasons for over-allocation were already analysed in Chapter 3. The caps defined in water sharing plans were unsustainable because they did not reduce the allowable extraction levels to the necessary degree (Interview with PM2). Consequently, although many water users were unable to withdraw water, some were allowed to do so, which exceeded the sustainable level of water extraction, as we know it today.

As a result, environmental damages were severe in the MDB, which lead to a changing awareness and knowledge about sustainable water extraction levels. The main reason for the inefficient planning was the self-management of the five Basin states[55] without cross-border coordination.

As Figure 7 illustrates, only a few sharing strategies were applied in the Basin scale such as state border crossing water trading rules or the Basin Salinity Management Strategy (Murray-Darling Basin Authority, 2011b). Main water planning instruments were regulated separately in each Basin state and each state was separately responsible to provide water plans. In this planning process scheme, coordination between states was not compulsory.

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[55] New South Wales, Queensland, Victoria, the Australian Capital Territory, and South Australia.

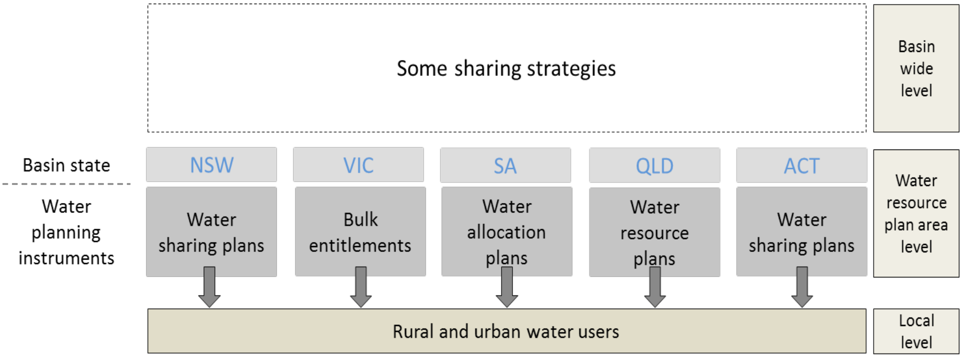

Figure 7: Water resource planning before the Basin Plan (before 2014) (Murray-Darling Basin Authority, 2011b).

Definitions and water planning instruments were very diverse, which also went along with different ideas at which levels water resources must be protected and when sources of water are over-consumed (National Water Commission, 2011a). For instance, uncoordinated water withdrawal occurred when one upstream jurisdiction planned to set a cap to a low river level (which was their understanding of sustainable river levels) and allowed intensive extraction until this level was reached. This had a significant impact on downstream water users and ecosystems. In these cases, water sharing plans resulted in conflicts between resource-sharing states, between water users (e. g. between different irrigators or between agriculture and urban water users), and between the environment (McKay, 2011, p. 616).

These user conflicts and damaging experiences in the MDB demonstrated that it is important to "develop a shared national understanding of sustainable levels of extraction and responses to over-allocation." (National Water Commission, 2008b, p. 21). Hence, by setting the caps too low and allowing water users to extract too many *resource units*, the whole *resource system* in the MDB was over-consumed.

The MDBA started to coordinate water consumption of the five riparian states that share water resources of the Murray River basin and the Darling River basin on a Basin level rather than a national level. With this step, water allocation levels (defined caps) should equal sustainable extraction levels, which in turn will prevent over-allocation of water rights and over-consumption of water.

4.1.1 The Basin Plan

As illustrated in the section above, each state of the MDB was separately responsible for water plans.

With the Water Act 2007 (Commonwealth) and the amendments to the Water Act 2007, an essential water reform for the MDB region took place. All Basin states accepted the Intergovernmental Agreement in December 2008 and gave their water resource management power to a single agency: the MDBA. (Sanders et al., 2010, p. 3).

For the first time, the MDB's groundwater, surface water and "environmental resources of the national heartland" (Murray-Darling Basin Authority, 2009, p. 2) will be managed as an integral unit by one institution. The MDBA is obliged to prepare a *Basin Plan* which is a "legally enforceable document" (Murray-Darling Basin Authority, 2009, p. 4) and sets

> "limits on the quantity of water that may be taken from the Basin water resources as a whole and from the water resources of each water resource plan area. It will also provide for the requirements to be met by the water resource plans for particular water resource plan areas" (Commonwealth of Australia, 2011, pp. Part 2, Division 1, Subdivision A, s 19).

In other words, the Basin Plan controls the share of water received by the environment and agriculture. The environment gets the preference and agriculture has to adjust more than it already does (Interview with PM2).

With this institutional initiative, it is hoped that long-term national interests (ABARE-BRS, 2010, p. 2) and sustainable water resource management of cross-border water systems will be realised.

In the preparation of the Basin Plan, a *Guide to the proposed Basin Plan* was published in 2010 by the MDBA for public consultation purposes. (Murray-Darling Basin Authority, 2010, p. ii). The Basin Plan came into effect in November 2012 and is now a Commonwealth law. Changes and various components of the Basin

Plan will come into effect during the next 6 or more years. The next step of the Basin Plan implementation involves the socio-economic issues of Basin communities to be able to develop state water resource plans (2012–2019). Furthermore agreements about constraints measures[56] have to be found, which are going to be implemented between 2014 and 2024. The Basin Plan will also look at the development of a Basin environmental watering strategy in 2014, and to adjust sustainable diversion limits (SDLs) in 2016. (Murray-Darling Basin Authority, 2013a and 2013b).

As demonstrated in Figure 8, supplementary to the Basin Plan, Basin states prepare water resource plans (Australian Government Department of Sustainability, Environment, Water, Population and Communites, 2011), which specify how much water is going to be available for water access entitlement holders, which are consistent with the requirements of the Basin Plan. Regarding those arrangements of water resource plans, water allocations will be determined by the Basin states in reflection of annual water availability. Those annual water availabilities may vary quite dramatically as already discussed earlier. Therefore, long-term average diversions are limited to no more than the SDLs. (Murray-Darling Basin Authority, 2010, p. 104).

As the MDBA announced in its concept statement 2009, the Basin Plan has several main functions:

- to "set and enforce environmentally sustainable limits on the quantities of surface water and groundwater that may be taken from basin water resources
- [to] set basin-wide environmental objectives and water quality and salinity objectives
- develop efficient water trading regimes across the basin
- [to] set requirements that must be met by state water resource plans
- improve water security for all uses of basin water resources." (Murray-Darling Basin Authority, 2009, p. 4)

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[56] "The Constraints Management Strategy will outline options to ease or remove constraints in ways that avoid 3rd party impacts before they occur." (Murray-Darling Basin Authority, 2013b).

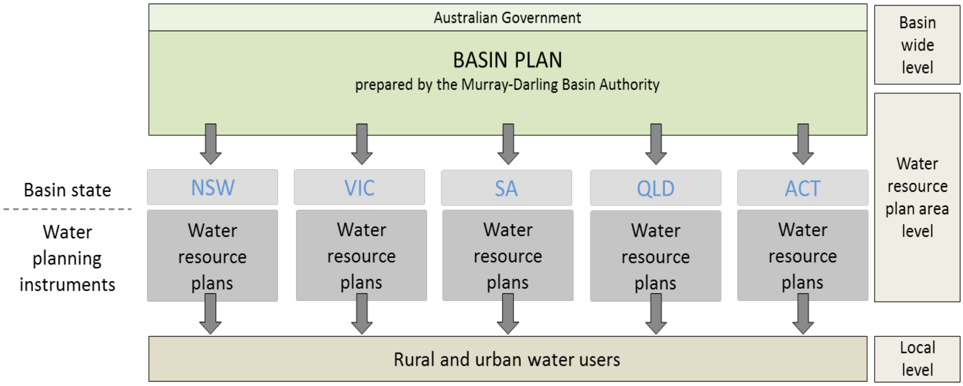

Figure 8: Water resources planning after the Basin Plan (Murray-Darling Basin Authority, 2011b).

The impact of the Basin Plan reductions on each water access entitlement holder depends on the implementation of the new water resource plans. This implementation will be the responsibilities of the Basin state governments. Consequently, water access entitlement holders will be affected differently by new SDLs. In some regions, impacts may be severe, while in others there may be no changes at all. (Murray-Darling Basin Authority, 2010, p. xxvii and 104).

The most substantial and (in the case of farming communities) the most feared change will be the introduction of new SDLs that will have a significant impact on the water consumption patterns in the MDB. This is explained in the following subsection.

4.1.1.1 Sustainable Diversion Limits

Currently in the water sharing plans of the Basin states, caps quantitatively limit water consumption from surface water. These caps are termed current diversion limits (CDLs) in the Basin Plan. One of the main problems is that "current Cap on surface-water diversions is set at a level based on historic use, not on what is sustainable." (Murray-Darling Basin Authority, 2009, p. 7). SDLs "represent the long-term average quantity of water that can be taken for consumption in any one year, i. e. the long-term average annual limit." (Murray-Darling Basin Authority, 2010, p. 104).

New SDLs only come into effect when the existing water sharing plans expire. This will be 2014 for Queensland, New South Wales and South Australia. In Victoria, new SDLs come into effect in 2019, which is quite a long period of time regarding the fact that extraction levels are not sustainable at the moment (Sanders et al., 2010, p. 3).

An additional problem is that groundwater resources are not protected by CDLs and are therefore used without being limited to a sustainable level. Considering water is finitely renewable, groundwater extraction should also be limited since natural assimilation capacities might be exceeded (see Subsection 2.1).

The introduction of long-term average SDLs that quantitatively regulate all kinds of water extraction as part of the Basin Plan is seen as the solution for the above-mentioned problems. Planned water extractions affect town, community, industry, and irrigation water supplies, as well as floodplain harvesting and interception activities, such as farm dams and forest plantation (Murray-Darling Basin Authority, 2010, p. 101).

The environmentally sustainable SDLs will "apply to the basin's water as a whole as well as at sub-regional levels" (ABARE-BRS, 2010, p. 5). Hence, water extraction will be regulated on the one hand for every single region in the MDB but will also be aggregated and regulated for the whole Basin region.

Scientific, social, cultural and economic knowledge plays a major role in the determination of SDL levels. There is still scientific uncertainty and a lack of knowledge that must be taken into consideration in the assessment of SDLs. (Murray-Darling Basin Authority, 2009, p. 7). The Basin Plan may not be able to meet the requirements of future risks and uncertainties concerning sustainable water management. As the past showed, knowledge about sustainable levels of water extraction changes. Additionally, the uncertainty about climate change, the unknown development of technological improvements and productivity as well as other uncertainties (which include groundwater resources, afforestation, bushfires, and increases in on-farm water storages) (Murray-Darling Basin Authority, 2010, p. 30) make it difficult to plan water usage in the long-term. In the draft of the Basin Plan, it is often pointed out that the MDBA is aware of uncertainties and limits in knowledge as the following exemplary quotes show: "a wide range of possible future climate conditions" (Murray-Darling Basin Authority, 2010, p. 106) "the best available information" (Murray-Darling Basin Authority, 2010, p. 35), "modelling platforms are the best available, it is important to recognise that there are inherent uncertainties in any mathematical modelling." (ibid.). However, water resource plans provided by the MDB-states will be accredited for a 10 year period (Murray-Darling Basin Authority, 2009, p. 14). This is still a long period of time and may not be able to take unforeseeable events (droughts, flooding, bushfires etc. with higher intensity than previously experienced) into consideration.

By providing a variety of SDL-scenarios in the MDBA's *Guide to the proposed Basin Plan,* different water levels, climate change, resource variability, and other risks should be taken into consideration (Murray-Darling Basin Authority, 2009, p. 7; National Water Commission, 2008b, p. 4). Addressing uncertainties and risks, the decision about proper levels of SDLs is very difficult and challenging when quantification of benefits and costs is incomplete. Additionally, it is challenging to represent the decision about SDLs to affected communities and strong interest groups such as the agricultural sector in the MDB. Therefore, decisions about water caps were highly influenced by short-term political interests, such as being re-elected by satisfying the lobbyists (see the following subsection). These targets are conflicting with the long-term goal of protecting the environment by gaining sustainable levels of water usage. As the interviewed experts confirmed, these conflicting targets lead to a weakening of water saving goals and delays in time concerning the adoption of the Basin Plan.

MDBA's scenario analysis

Since water systems are over-allocated especially during drought periods under existing schemes, the draft of the Basin Plan provided by the MDBA considers long-term average SDLs of additional water for the environment between 3,000 GL/year[57] and 7,600 GL/year (Murray-Darling Basin Authority, 2010, p. 101). In the lead up to the proposal of the Basin Plan, three scenarios were analysed by the MDBA. The first scenario proposes an additional volume of

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[57] The minimum of 3,000 GL/year equals approximately the annual volume of water consumed from rice and cotton industry together in the MDB in 2011–12 (rice: 1,133,532.4 ML; cotton: 1,905,918.9 ML) and is at the same time about half of total agricultural water consumption of 6,173,529 ML in the MDB in 2011–12 (Australian Bureau of Statistics, 2013b, Table 2).

3,000 GL/year[58] for the environment[59], the second 3,500 GL/year, and the third scenario aims to provide 4,000 GL/year of additional water for the environment. Since the "Authority feels that the escalating social and economic effects are likely to outweigh the additional environmental benefits" (Murray-Darling Basin Authority, 2010, p. 110) in scenarios above 4,000 GL/year for the environment, analysis was limited to the three above-mentioned scenarios.

In each scenario, the volume of water for human consumption is decreased by a minimum of 3,000 GL/year. Since agricultural production is the main water consumer in the MDB (see Subsection 3.2) irrigated agricultural production will be affected most by the new SDLs (Sanders et al., 2010, p. 3; ABARE-BRS, 2010, p. 5).

Even though SDLs quantitatively reduce the long-term average of water consumption by definition, it is still not clear to which extent this will be realised by the MDBA within the Basin Plan. Figure 9 shows one possible re-allocation-scenario where water for consumption is decreased by the SDL-implementation equally in drought (t1, t3, t5, t7) and wet periods (t2, t4, t6) to provide additional water to the environment. This means that the environment receives a constant amount of additional water independent of water availability and water flows.

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[58] Which is e. g. the difference between the upper and lower red dashed horizontal line in Figure 9.

[59] With the result that the "Flow through the Murray Mouth would, on average, increase from 5,100 GL/y to 7,100 GL/y – an increase of 2,000 GL/y." (Murray-Darling Basin Authority, 2010, p. 127).

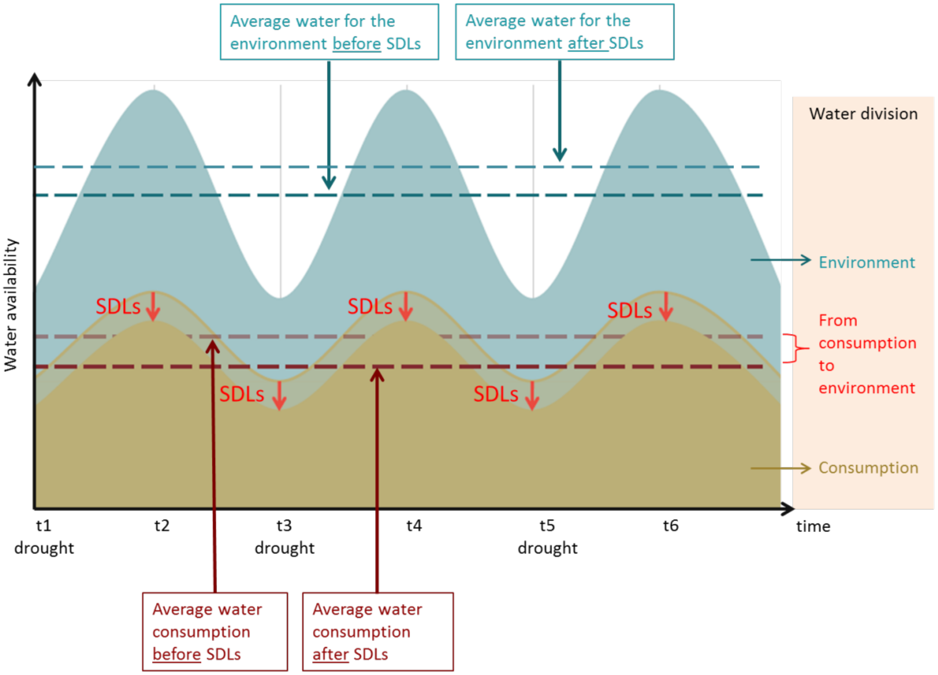

Figure 9: One possible application of SDLs with effects on water consumption (Appels and Briggs, 2011, p. 13).

The figure above illustrates a homogeneous scenario by re-allocating water from agricultural consumption to the environment. The proposal of the Basin Plan provides no specific information about SDL-implementation-patterns with the consequence that several scenarios are possible to receive the average long-term SDL on water consumption.

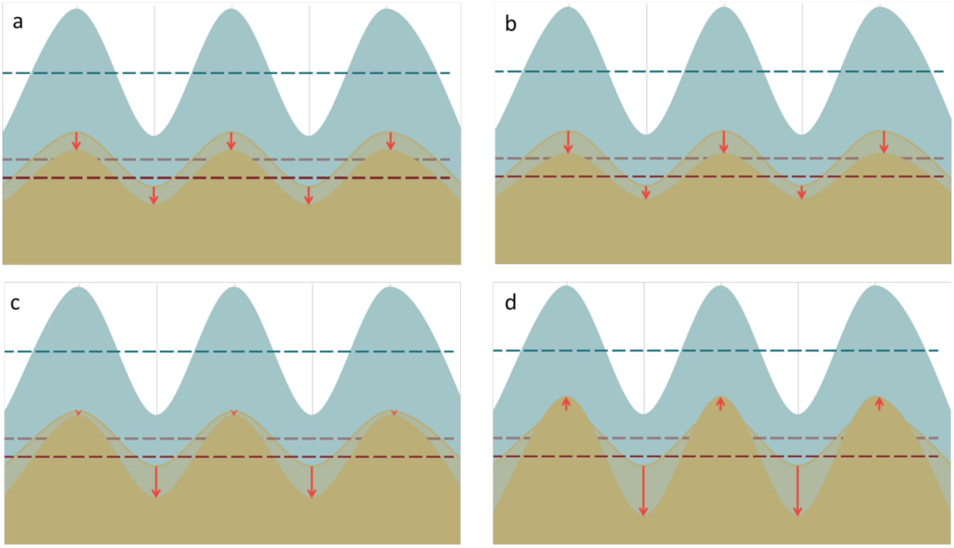

Figure 10: Comparison of possible variation of SDLs with effects on consumption (Appels and Briggs, 2011, pp. 12-15).

Figure 10 shows different approaches for the implementation of SDLs.

a: During dry and wet periods, the same amount of water is taken from consumption to support the environment (approach illustrated more detailed in Figure 9).

b: During dry periods less water is taken from consumption than in wet periods. Comparing with the other re-allocation approaches, this method reduces the variability of available consumption water between dry and wet periods the most. Therefore, this might be the favourite approach for irrigating farmers.

c: Nearly no water is taken from consumption during wet periods but more water is taken during dry periods. This scenario would decrease variability of water for the environment but increases variability of available water for consumption.

d: During wet periods, more water is supplied to consumption than before the introduction of SDLs. For compensation, a large amount of water is taken from consumption during dry periods. In this case, the variability of water, which is available for consumption, is highest when compared to the other approaches. This method would afford high adaptation capabilities. From an environmental point of view, human induced water variability is lowest in this scenario.

The type of approach for the implementation of SDLs will be crucial for farmers since they depend on a reliable level of available water for irrigation. Farmers with perennials might be particularly affected by the c and d approaches, since there might not be enough water available to keep their plants alive during droughts. Even if there is little irrigation water available, prices reflecting water scarcity would be very high. In the long term, these farmers would not be able to cultivate crops, which need to be irrigated if water is not available or they would not be competitive with crop imports due to the high cost of production. A well-considered strategy for SDL-implementation with weighing interests and environmental consequences is supportive to achieve political goals successfully and limit negative consequences on affected communities and farmers (see experts' opinions below).

The institutional effort required for the *Guide to the proposed Basin Plan* implementation was enormous. The preparation of knowledge pertaining to the environmental, social and economic impacts of potential water cutting levels in the Basin required the input from many scientists (see Subsection 1.1). The whole water planning process entails transaction costs, which should be smaller than the benefits the implementation brings. If this is not the case, the initial situation is not improved.

Interviewed experts confirmed that farmers have a strong lobby that makes it more difficult to achieve such a water planning strategy as the following shows.

4.1.1.2 Experts' Opinions and Reactions to the Proposed Basin Plan

In cases of conflicting targets, the realisation of one goal (e. g. food security) interferes with the achievability of another goal (e. g. environmental health). By prioritizing the achievement of one goal, others are neglected.

A representative of farmers stated that the proposed Basin Plan is not balanced and is focused on the environment (Interview with FR2), despite the fact that existing uncertainties about the level of sustainability remain. An interviewed policy maker addressed the problem of uncertainties regarding environmental benefits and needs by asking the following questions: What is sustainability for ecosystems? How should farming be sustained? And are we going too far or are we not going far enough to get that balance (Interview with PM2) by applying a water sharing plan? Those questions remain unanswered today but provide the basis for discussions for opponents of the Basin Plan.

The farmers' representative claimed there is a need to balance the objectives of environmental policy, food policy, and economic development in both the less populated areas of the MDB (since 95 % of the Australian population lives within 50km off the coast) and the more populated areas as well as a review of the migration policy[60] (Interview with FR2).

The main reason for the heated debates and emotional reactions to the proposed Basin Plan is that with this WMP, the primary goals have switched from agricultural support to environmental protection. The *Guide to the Proposed Basin Plan* clearly prioritizes environmental issues, which has lead to extremely emotional reactions from potentially affected groups. "In Griffith, a town near Narrandera, militant farmers burned piled up copies of the water-use plan" (The Economist, 2010). The main argument was the fear of job losses (which is assumed to be about 800) and a depopulation of farmers' inland communities, which rely on agricultural production (McKay, 2011, p. 618 f.). Urbanisation is a typical characteristic when structural changes occur in an economy (from agriculture towards an industrial and service-providing economy).

Potentially disadvantaged farmers and communities are very unsatisfied since they invested into the MDB inland and trusted on an irrigation supporting policy. "The reason why we are having so much difficulties in the water reform of Australia is that, […] there are always investment that have been made, towns grow up around irrigation communities and status quo is a high thing to shift." (Interview with 6a-c).

Interviewed policy makers are aware of the impacts of the Basin Plan on irrigators. The water dependent communities that derive their income from irrigation farming may not exist in future since there are no other employment options

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[60] The Australian population is predicted to increase from 22 million to 30 or 35 million in the future (2050). (Interview with FR2).

available (Interview with PM2). Therefore the Basin Plan determines the future of "17 threatened communities". (Interview with FR2). This raises a discussion about equity and who will be the winners and losers of the Basin Plan. An interviewed policy maker sees smaller agricultural towns in the Basin as the losers of the policy. "Those who benefit [live] in the capital cities, who are worrying environmental humanity […] and ecological outcomes, but […] their livelihood does not depend on it directly, whereas if you are a farmer, obviously water is a direct input." (Interview with PM2).

One interviewee argued, because politicians want to be re-elected (Interview with PM2), they have loosened the objectives of the Basin Plan by making "an election commitment" (Interview with S6a-c) and taking less water from irrigators than needed to accomplish environmental targets.

Due to the Australian elections, the publishing *Guide to the Proposed Basin Plan* was delayed until after the vote, which slowed down the necessary adaption process (Interview with S7). This demonstrates not only how difficult it is to enact a policy that restricts water to the agricultural community but also how fearful politicians are about losing votes and how influential the farmers' interest groups and lobbyists are in fighting for their interests.

Governments plan to combine different WMPs to close that gap between sustainable and proposed Basin Plan water extraction levels. In addition to water reductions by the Basin Plan, they plan to buy the remaining volume by another round of buybacks (see Subsection 4.2) that might cost another AU$ 3 billion. (Interview with PM2 and S6a-c). Furthermore, governments plan to support affected communities during the adjustment period when towns decrease in size. Farmers' families also have the opportunity to apply for "exceptional circumstances payments" when a region is severely affected by droughts, bushfires, and bad frosts, which increase the financial burden on farmers. (Interviews with S6a-c and S7).

Most experts assessed the situation of farmers in the MDB as very difficult during droughts but manageable. This is because farmers are "smart" and already very flexible by adapting to the variability of available water (Interviews with S4, S5, S6a-c, S7, FR2 and PM2). Even if the Basin Plan reduces consumption water availability up to 30 %, farmers are supposed to find a way to adapt to the new situation. Farmers understood "the need to get more water flowing down rivers." (Interview with S7).

4.1.2 Conclusion to Water Sharing Plans

After the MDBA published the *Guide to the proposed Basin Plan* it is still uncertain how much less water will be available for consumption by the implementation of long-term average SDLs. Furthermore is unclear, which of the possible variations of SDLs will be implemented. High uncertainties are the reason for heated discussions, emotional reactions and general dissatisfaction and only fuel the fears of farmers. They argue that the MDBA underestimates social impacts and economic losses caused by SDLs (Jiang, 2011, p. 277). Scientists estimate economic impacts on irrigation industry to be quite high. It is expected that the gross value of irrigated agriculture production (GVIAP)[61] will be reduced by 15 % and the profit gained from irrigated crop production could be reduced by 8 % in 2018–19 in the event the consumption water is reduced by 3,500 GL (ABARE-BRS, 2010, p. 2). However, the MDBA plans to "provide a phase-in period for SDLs of up to five years" (Murray-Darling Basin Authority, 2010, p. xxix), which should enable farmers and communities to adapt to a decreasing water availability.

During the last 15 years, farming has already experienced difficulties caused not only by the long lasting drought but also by the subsequent flooding. In the future, farmers will have to face even more severe droughts due to climate change (see Subsection 1) with less consumption water available. This situation will only worsen with the introduction of the SDLs.

However, with respect to sustainability, in the past farmers were consuming too much water especially during droughts since state governments announced too much water as available for irrigation issues since 's were too low. The political objectives to support irrigation farming in the MDB and the lack of cross-border coordination of water right provision led to severe environmental problems and unsustainable water extractions. Therefore, governmental failure occurred in the MDB, which must be corrected. The Basin Plan and the introduction of SDLs

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[61] "GVIAP refers to the gross value of agricultural commodities that are produced with the assistance of irrigation." (Australian Bureau of Statistics, 2010g). See Appendix 7.6 for detailed definition.

is the framework for a non-pricing, non-monetary strategy that defines new limits of maximum of extractable water. Those limits should prevent over-consumption of water and resulting environmental damages on a Basin-wide scale.

Even though the Basin Plan is a mandatory instrument, it does not provide overall incentives for farmers to save water voluntarily and use water resources efficiently since not all farmers will be affected to the same extent by water reductions. Additionally, it causes high transaction costs due to big institutional investments. Consequently, costs must be weighed up against potential benefits (which include benefits for the environment) since the introduction of water managing instruments is only meaningful when benefits exceed costs.

4.2 The Restoring the Balance Program

The RtB program (also called the Commonwealth buybacks or the buyback strategy) is part of the *Water for the Future* program and has the objective to restore the overall health of the environment in the MDB.

This is supposed to be realised by buying permanent water rights (water access entitlements) from willing sellers to give the water back to the environment. (ABARE-BRS, 2010, p. 12). This is done by providing high monetary incentives[62] for water right holders (Interview with PM1) by offering higher prices for water access entitlements than average market prices.

Over a ten-year period (starting in 2008–09), there are plans to invest AU$ 3.1 billion (National Water Commission, 2010c, p. 7). Between 2008–09 and 2010–11, the Australian government has already spent AU$ 1.5 billion (Hone et al., 2010, p. 1) by actively participating in the water trading market.

Hence, this strategy aims to restore the balance between water users and environmental health in the long-term by purchasing water access entitlements from willing farmers (National Water Commission, 2011d, p. 73). This instrument is a timely limited tool to perpetually reduce the quantity of available water access entitlements on the water market.

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[62] By financially compensating selling farmers for giving up opportunities to use water which is seen as a fair procedure (Interview with S1).

From 2007–08 to December 2011, about 3,150 irrigators (15 % of all irrigators in the MDB) sold water access entitlements to the government (Marsden Jacob Associates, 2012, p. i).

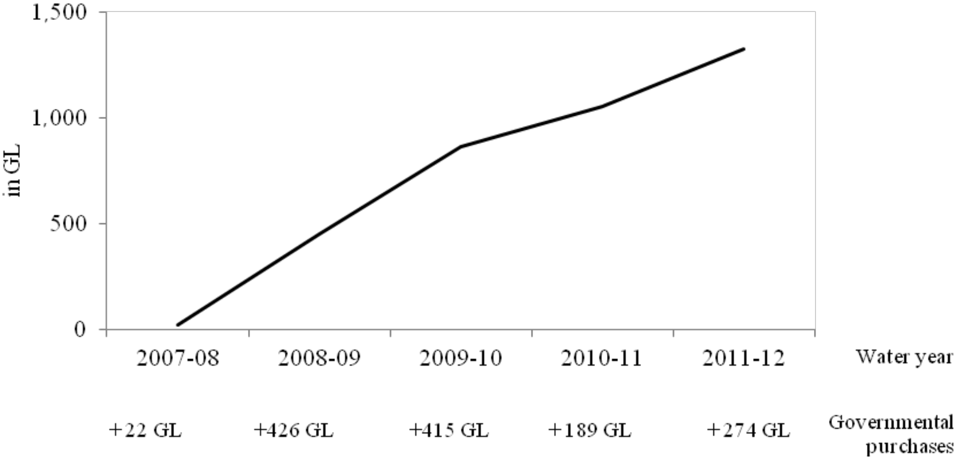

Figure 11: Accumulated volume of water access entitlements purchased by the Australian government in the RtB program (National Water Commission, 2013a, p. 63).

Figure 11 shows governmental purchases accounting for more than 20 % of Basin wide water access entitlement trading activities since 2008–09 (National Water Commission, 2013a, p. 62). Since the governments' involvement in the water market is very significant, it has had a considerable influence on the demand for water access entitlements and the prices paid. Overall, the RtB program has raised the market price for water access entitlements due to the fact that the prices paid by the Australian government were higher than the actual market price (Interview with S8). On the one hand, this price manipulation has had a direct impact on the market equilibrium and falsifies statements about the demand for, and the supply of water rights on the market. Therefore, the market price is no longer an indicator for the availability of water rights. On the other hand, it might help farmers in debt especially in times of drought to prevent market exits by selling parts of their water access entitlements.

The Australian government bought a total of 1,326 GL of water access entitlements from 2007–08 to 2011–12 as shown in Figure 11. Most water access entitlements were purchased in 2008–09 with 426 GL and in 2009–10 with 415 GL. Purchases decreased in 2010–11 to a volume of 189 GL water access entitlements and again increased to 274 GL in 2011–12. (National Water Commission, 2013a, p. 63).

Most sales to the Australian government's RtB scheme come from the agricultural industry and farms. For instance, the company *Twynam Agricultural Group* sold 240 GL of water to the Australian government (National Water Commission, 2010b, p. 140).

All water access entitlements, which are bought by the Australian government are managed by the *Commonwealth Environmental Water Holder*. This institution decides, which water body or river system gets the additional water with the goal to restore the environmental assets and to protect ecosystems. (National Water Commission, 2010c, p. 8).

The average price paid by the Australian government was AU$ 2,300/ML in 2007–08 (Hone et al., 2010, p. 1). This means that an average of AU$ 50,600 was invested for the buyback of 22 GL water access entitlements in 2007–08. Average market prices for traded high security water access entitlement (all trades are considered, not just buybacks) were above AU$ 1,500/ML from 2007–08 to 2011–12 as illustrated in Table 2. That means that the intervention of the Australian government in the water right trading market caused increasing water prices for water access entitlements. Hone et al. (2010) estimated that prices are approximately 13 % higher in the northern MDB and 18 % higher in the southern MDB as a result of governmental intervention. (Hone et al., 2010, p. 2).

The price increase induced by the government is a huge disadvantage in terms of a free market and flexibility of market prices because the price does not reflect the actual relation of supply and demand on the water trading market. But a price increase can also be an advantage for water right holders. Policy makers see the RtB program as a possibility for farmers to choose whether they want to stay in business or whether they want to sell their water access entitlements to the government while being fairly compensated (Interview with PM1). In farmer surveys, scientists found out that a number of farmers were willing to give back some of their water to the environment (Interview with S7). However, as a result of drought, some farmers were deeply in debt and were being encouraged to sell their water access entitlements to the government by the banks. In those cases, farmers were more or less forced to sell their water access entitlements (Bjornlund et al., 2011, p. 291) to gain profit from the sales.

In the course of the Basin Plan (see Subsection 4.1.1), the Australian government plans to extend the buyback of water access entitlements to accomplish the aims of the SDL-approach. Since the Basin Plan reduces the amount of water to be used for consumption, the Water Act 2007 (Commonwealth) intents to provide compensation payments to those water access "entitlement holders where volume or reliability of their water access entitlements is compulsorily reduced as a result of a reduction in SDLs" (National Water Commission, 2011b, p. 49).

Hence, WMPs in the MDB under the Water Act 2007 (Commonwealth) can be analysed separately, but are interlinked strategically.

4.2.1 Experts' Opinions about the RtB Program

Experts' opinions about the RtB program are diverse. Some believe the program is the most efficient solution to reduce water consumption in the long-term since farmers get paid for selling their water access entitlements. Farmers receive a compensation (Interview with S1 and S8) for the sold water right "which is private right guaranty" or what politicians refer to as an equity argument (Interview with S1). This helped farmers to receive a higher price for sold water access entitlement (Interview with S4).

Others doubt the voluntariness of all farmers selling their rights during drought since many were deeply in debt and were being pressured by banks to sell water access entitlements (Interviews with S4, S6a-c, S8, PM2, FR1a and FR1b) to the Australian government. Once all or parts of the water access entitlements are sold, no water or less water can be used by the farmers. This may force them to leave the market during the next drought when water rights are more expensive and they cannot afford to buy them. One interviewee noted (Interview with PM2) that the government does not seem to be concerned about what happens to the selling farmers and the irrigation sector in future.

Experts feel that the RtB program is a very cost intensive instrument that "takes a big budget" (Interview with S6a-c). Those costs are covered by taxpayers who pay for internalisation of externalities. Consequently, the causer (in previous sections also called the polluter) of the externality that is the irrigating industry benefit twice from their damage-causing action since they first gained profits from over-using water and then gain higher prices for selling water access entitlements within the RtB program. In this context it must be mentioned that irrigators may not be responsible for environmental damages since political targets supported the irrigating industry and farmers tried to maximise profits. Consequently, the main reason for environmental damages is governmental failure.

Additionally, buying back water access entitlements has a strong impact on upstream and downstream markets. Businesses that rely on the "expenditures from farms are affected too and are [maybe] more concerned about buybacks [than farmers itself]". (Interview with S7).

4.2.2 Conclusion to the RtB Program

The RtB program is a long-term method of resolution for Australia's rural water problems during drought periods.

By buying water access entitlements, the Australian government intends to restore the MDB and give the water (which was beforehand provided to irrigators to a too large extent) back to the environment. The RtB program is an instrument that quantitatively reduces available water rights on the permanent water right market until a desired maximum quantity of available water rights on the water market is reached or the financial capacity of the Australian government is exhausted. Although some farmers may have sold their water access entitlements as a result of droughts, principally the RtB program is a voluntary instrument that compensates sellers with a price that is higher than the market price for water rights.

Even though the environment is thought to benefit from this instrument, the success largely depends on the maximum extraction levels announced by the state government (in future by the MDBA). Assuming that water allocation levels for each water entitlement will not increase in the future, the quantitative reduction of entitlements due to the RtB program can lead to reduced water consumption, which is beneficial for the environment. If institutions announce more water being allocated to each water access entitlement, it could result in the same volume of water being extracted in the future and that no improvement towards sustainable extraction levels is achieved. Hence, the meaningfulness of the RtB program must be critically evaluated since the Australian government only focuses on buying water access entitlements (not water allocations) without having direct influences on the Basin states' water sharing plans and state governments' extraction level announcements.

Furthermore, this market intervention is very cost-intensive and is a burden on taxpayers. However, it is a long-term market-based instrument to quantitatively reduce available water access entitlements on the water markets in the MDB. If combining the RtB program with a reduction of available water for consumption in the manner of the Basin plan (or at least keeping announcements for water allocations on the same level as in the past), over-consumption and the resulting environmental damages are expected to decrease in the future.

4.3 Water Pricing

The price for a good resulting on a free market is an indicator for its value and scarcity. Generally speaking the scarcer a good, the higher its value and market price. This works for a large variety of goods including gold, diamonds, and cars. In these cases, high prices exclude consumers who are not able to pay the market price that allows only a limited number of consumers to participate.

Since water is a necessity of life, this simple formula of exclusion would have socially unacceptable results. However, irrigation is – at least in Australia – not a basic need (see Footnote 15 for definition) since irrigated crops could be imported from water rich countries or crop production could be reduced to climatic adapted crops that do not need to be irrigated. Therefore, this thesis does not concentrate on water pricing policies that must include affordability or basic needs approaches but focuses on water pricing for agricultural industry and crop irrigating farms.

As already mentioned, the water price should reflect the scarcity of water by including the economic value of water as a natural resource (Solanes, 2001, p. 262) and the water price should contain opportunity costs that are costs “measured in terms of the next best alternative forgone” (Sloman, 2003, p. 121). This next best alternative is not chosen but reflects the price users would have to pay in cases where water sources are not available anymore. In this case, its access would involve higher costs that also arise when the quality of water diminishes.

On the other hand, the market price of water should cover costs for all “water related services and connected added value and expenses” (Solanes, 2001, p. 262). Those service-related costs of water service providers include fixed costs (e. g. processing or administration costs) and variable costs (e. g. costs for maintenance and water delivery).

If not all accruing costs are covered by the price water users have to pay (private costs) on the market, external effects occur as previously discussed in Subsection 2.2.3. If market forces cannot balance supply and demand and do not lead to an adequate water price, institutional intervention could be a solution. Water pricing strategies such as tariffs, taxes, and different charging methods (e. g. two-part, single-part or multi-step tariffs) can be such instruments.

Regarding the problems of over-consumption of water and inadequate water pricing in the MDB (see Chapter 3), water-pricing strategies may solve those problems. In the past, fixed water prices for water deliveries did not mirror water scarcity, suppliers’ full costs or included externalities. Hence, water prices were predefined at levels that were too low. Water pricing policies might be a solution to correct these inadequacies by increasing the water price.

Water pricing instruments can be used to manage water demand (in the case of the MDB, to decrease demand) or as a costs-oriented regulation to cover costs of water suppliers (Franco-Dixon et al., 2007, p. 29). Both targets are discussed separately in the following and represent potential policies for the Basin.

4.3.1 Cost-Oriented Regulation

The cost-oriented approach implies that the government defines a market water price, which is meant to cover supplier’s costs and allow a possible profit margin.

To prevent natural monopolies from misusing market power, governmental intervention was seen as unavoidable (Oelmann, 2005, p. 58) in cases of competition policy exceptions with an antitrust release of sectors (Knieps, 2001, p. 79).

To enable the government to establish a market price, which orientates on supplier's costs, tremendous effort needs to be applied to determine operating and capital costs that need to be reported by the water supplier. Hereby, information asymmetries may result from incorrect information or misinterpretations of provided data. Consequently, cost-oriented regulations create high costs due to the complexity of effort that must be invested to determine the water price. (Oelmann, 2005, p. 58 f.)

In addition, the suppliers' goal of profit maximisation is in conflict with the aim of welfare maximising by the government (ibid.). The consequence could be that suppliers have no incentives for innovation or cost minimisation when monopolists' opportunities of maximising profit are strongly limited by regulations. If the governmental target of welfare maximising is too ambiguous and therefore water market prices are too low, unacceptable low profit margins or even deficits would be the consequence. In this case the government has to pay compensation to prevent market exit of the monopolistic supplier.

As the experiences in the MDB showed, especially during droughts, revenues from water sales did not fully cover costs of water service providers (which indicates that the predefined water price was not high enough) and subsidies had to be paid by the governments. Indirectly, those subsidies also support farmers since the market price they have to pay is lower than the marginal costs of the monopolistic supplier. This results in a higher water demand due to affordable water prices and water consumption that might exceed sustainable extraction levels.

Hence, subsidies are counterproductive in terms of creating incentives for water savings and lead to external effects. Since the government finances their subsidies to water suppliers with tax incomes, taxpayers more or less refinance the difference between external marginal costs and private costs.

As long as water charges are subsidised in the MDB, they are not able to reflect water scarcity and the incentive for water efficiency is lacking with the consequence that water is used unsustainably. The National Water Commission

(2009b) already recommended “Cost-effective pricing in both the rural and urban sectors [… to provide] signals to water users that encourage efficient usage and investment decisions. Efficient pricing should reflect the full-costs of water services, including any environmental externality impacts.” (National Water Commission, 2009b). This knowledge and awareness should be implemented into the practise of water pricing in the MDB. The water pricing instrument of cost-oriented regulation can either be seen as a strategy to correct governmental failure, which was caused by subsidies or as a command and control instrument that forces water suppliers to cover costs without being subsidised anymore on a mandatory basis (Perman et al., 2011, p. 195).

By stopping governmental support and eliminating subsidies for water suppliers they should be allowed to cover costs by water sales. By this approach four effects can be achieved:

Firstly, water charges vary reflecting water suppliers’ costs as well as fluctuations of water sales depending on state governments’ announcements on how much water is available for irrigation issues. When water is abundant, the water charges would be consequently lower since total costs can be covered by more water sales.

When low irrigation water deliveries are announced, water charges should be higher, since suppliers have to cover costs with less water sales. Higher water prices in turn cause a decrease in water demand since not all water users are willing to pay more. The environment would benefit from this decrease of farmers’ water consumption. Water inefficient users are excluded from consumption by market forces. The advantage is that the price reflects actual availability of irrigation water (not general water availability or “true” water scarcitysince the price does not include opportunity costs and externalities) and provides an incentive to efficiently use water when it is limited. With higher water charges, the production of water low value crops will be reduced by market forces and water is re-allocated to the higher valued crops. Hence, subsidy removing enables a development towards allocation efficiency.

Secondly, money, which was originally used by the governments as subsidies to cover costs of irrigation water suppliers, does not have to be paid anymore by taxpayers. This reduces the financial obligations of taxpayers and closes the gap between external and private costs.

The government could also decide to still charge the money but re-invest it in the research and development of the irrigating sectors with the effect that for example more water-efficient technology is used and water saving long-term goals can be achieved.

The third effect of a subsidy removal is that water suppliers get the incentive to reduce costs if the new set market price (which should cover suppliers‘ costs) is still incapable of full-cost recovery. Former subsidised monopolists have to improve allocative, productive, qualitative, and dynamic efficiencies that may not be gained under subsidising policies (see Subsection 2.2.2).

Finally, subsidies distort international crop markets and give Australia a competitive edge that would not exist without subsidising irrigation water. Crop prices can be comparatively lower due to lower production costs of subsidised Australian farmers. By removing subsidies for irrigation water, incentives for other ways of gaining a competitive advantage may arise. For instance, Australian agricultural industry may increase water efficiency by investing in water saving technologies and innovations or just concentrate on the cultivation of water high value crops that can be produced at lower costs and with less input factors.

Hence, removing governmental support may not only have positive effects on the environment, it could also improve economic efficiency. This would be a “win-win” situation from a macroeconomic point of view. By changing the policy objective from water suppliers’ and irrigating farmers’ support to environmental protection, a trade-off between those targets must be expected. (OECD, 1998, p. 7). “Losers” of the subsidy removing policy would be irrigating farmers facing higher water prices since monopolists are expected to pass along all costs directly to their customers[63]. The impact on the irrigation industry are analysed in the third scenario (see Subsection 5.1.8.1) of this research. By applying this cost-oriented water-pricing scenario it is clear that the water price must be much higher than before to cover suppliers’ costs. In this scenario, opportunity costs

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[63] Which is expected to be advocated by the independent institutions (which are empowered to suggest maximum water prices, the supplier is allowed to receive from water users) since they are aware about full cost recovery necessities.

and the “true” value of water are not included in the water price. This would lead to an additional increase of water charges.

4.3.2 Demand Managing Water Pricing Strategy

When the regulating instrument of water pricing has the goal to influence the volume of demanded water, it can either be increased or decreased in comparison to the equilibrium water prices in free markets. Since there are already environmental problems due to water over-consumption in the MDB, strategies targeting an increase of rural water demand are not considered in the following.

Focusing on demand decreasing strategies, various water pricing instruments may be applied.

One possible instrument is a permanent price fixation, which is not a market-based solution to influence the water demand. By fixing the water price on a high level, variability of available water is ignored and economic losses must be accepted. Reasons for this approach might be that structural changes in an economy should be accelerated (from agriculture towards an industrial and service-providing economy) or that water efficiency should be permanently improved and/or water demand permanently decreased. Interviewed experts confirm the direct correlation between water pricing and water use efficiency: “When [the] price of [water allocations] started going up [during the drought] it was amazing how much more efficiently people could use it.” (Interview with S6a-c). “If water has a[n appropriate] price, people will value it more.” (Interview with S3).

After the drought was over and water right trading prices decreased in the MDB, water efficiency decreased again (Interviews with S7 and FR2). If transferring the experiences from the water right trading market onto the water delivery market, it might be an incentive to implement such a high water price fixation. However, when fixing water prices at a high level without acknowledging water availability, water would be much more expensive during wet years than the level of marginal social net product and therefore cause economic losses. This might not be intended by a demand managing water pricing strategy.

A more market oriented solution of demand management is the introduction of an incentive based quasi-market instrument. Pigou (1932) suggested that the government may introduce "extraordinary restraints" (Pigou, 1932, p. 192) in the form of a tax in cases in which the "marginal social net product is less than that of the marginal private product" (ibid., p. 224), which describes the external marginal costs (see Subsection 2.2.3). The main position of Pigou is to charge the polluter of the environmental damage and the negative externality with a tax. The rate of tax T equals the external marginal costs that arise in the social optimal situation. (Endres, 2013, p. 115 ff.).

In times of drought, when water is scarce, environmental damages are caused if farmers keep unsustainably extracting water for irrigating issues.

Since many farmers are involved, one can speak of a whole industry causing environmental damages (ibid.). These damages are not included in the market price of water, in the case of the MDB. In that circumstance, the marginal private product exceeds the marginal social net product. By taxation, an internalisation of external effects is possible. Taxes on water (as an input factor for irrigation industry) have the goal to internalise externalities and to provide incentives for irrigators to use water efficiently. A degressive tax, which rate $T(q_{w\,avail\,tax})$ increases as the amount of subject to tax (here the volume of extractable water $(q_{w\ avail\ tax})$) decreases, could prevented such environmental damages and is therefore included in the scenario analysis of this research.

The Pigouvian *environment compensating irrigation tax,* developed by the author, is such a degressive tax. This tax is voluntarily[64] since rational behaviour of market agents (firms aim for profit maximisation while individuals seek utility maximisation) leads to a decrease of water demand. (Perman et al., 2011, p. 195 ff.). By this rational behaviour of the irrigators, the total costs of controlling water consumption will be minimised. Therefore, the Pigouvian tax is seen as the solution causing the least costs. (Paulus, 1995, p. 27 ff.). This simulates market driven water pricing and provides incentives for water savings and sustainable demand behaviour.

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[64] Voluntarily means to create incentives for market agents to "voluntarily change their behaviour" (Perman et al., 2011, p. 195).

The environment compensating irrigation tax is an earmarked tax that is directly used (and spent) by the government to compensate the environment for water losses and occurring damages that are the results of irrigation activities by financing environment protection programs, and desalination projects etc. Hence, with the introduction of such a tax, water consumption is decreased when less water is available for extraction with the consequence that environmental damages decline and external effects are internalised. Additionally irrigators receive incentives to invest in water efficient technologies and adapt irrigation, and agricultural practises, which stimulates economic development.

Despite the advantages of a taxation water pricing strategy, the government depends on the responsiveness of water users to price signals or in the agricultural case, on the water price elasticity of demand for irrigation water (see Subsection 3.3.3.1). Since the responsiveness of irrigators largely depends on the water price levels, the initial market water price and the tax itself must be high enough that the behaviour of water users changes as desired. If the tax and/or the initial market price are too low, a taxation system does not provide much incentive to change the behaviour and externalities remain (or are not internalised to the desired extent).

Therefore, the authority, which sets the tax, requires full information about the extent of externalities as well as relevant benefits, costs, and the potential environmental damages that might occur in the manner of water usage for irrigation issues (Paulus, 1995, p. 27 ff.). In fact, Pigou (1947) confirms that it is difficult to gather the necessary information: "How are we to make the corresponding calculation for [… such damages …] plainly the difficulties are formidable. […] The relevant knowledge is of a sort that we do not at present possess" (Pigou, 1947, p. 42 ff.). That this lack of knowledge still exists nearly 70 years after he wrote those words was already explained in Chapter 2 when addressing water market failures caused by information asymmetries and difficulties in assessing water's value.

Consequently, the level of tax must be evaluated carefully by taking all available information (which should be enlarged by future research) into consideration. Economic, social, and the environmental impacts of those regulations must be controlled, monitored, and will eventually need to be corrected at different levels of taxes if the desired targets are not achieved.

When free markets fail (due to natural monopolies or external effects), the taxation system may be a market-oriented solution to mirror the volume of extractable water, and to control water consumption. The impact on irrigated production and water consumption of irrigators by the potential environment compensating irrigation tax (which is an example of such a Pigouvian tax) is analysed in scenario 4 (see Subsection 5.1.8.2).

4.4 Interim Conclusion

This chapter illustrates the general characteristics as well as the advantages and disadvantages of existing and potential institutional arrangements. All four considered WMPs have as their main objective to reduce over-allocation of water in the MDB by either applying non-pricing or pricing solutions.

The first observed strategy is the non-pricing, non-monetary strategy of water sharing plan. To replace the Council of Australian Government agreement, which defined an MDB-wide cap of 11,500 GL/year, the Basin plan aims to reduce this cap on extractable water to a maximum average of 4,000 GL/year. This cap-reducing policy diminishes irrigation water availability on a Basin scale that should prevent from over-allocation in the future.

As pointed out in Chapter 3, another reason for over-consumption of water is the quantity of existing water access entitlements. After allowing irrigators to sell unused water rights on the trading market, more water was used than before 1995. The consequence is that existing permanent water rights cannot be fully allocated, which is an indication that the quantity of water access entitlements must be reduced. This is the intention of the non-pricing, monetary institutional arrangement of the RtB program. In the manner of this RtB program, the Australian government participates on the water market by buying water access entitlements from willing farmers to quantitatively reduce permanent water rights on the market. As a result, less water can be used by irrigators and therefore this approach might be a solution to correct previous over-consumption assuming that water allocations levels do not increase.

Another reason for over-consumption in the MDB is inadequate water pricing, which predefines and fixes water prices for water deliveries to a low level. Those prices are not even able to cover costs of water suppliers. As a consequence, the state governments cover suppliers' costs to a great extent. The third potential institutional arrangement removes those governmental subsidies and grants. The goal of this cost-oriented, mandatory pricing strategy is to reduce over-consumption of water by achieving a level of rural water prices that are able to fully cover the costs of water providers. When applying this pricing strategy, the water price increases when the quantity of water sales decreases.

The fourth WMP is a potential institutional arrangement, which aims to reduce water consumption by internalising externalities during times when water is scarcer. This could be realised by applying a Pigouvian tax when the tax rate depends on the volume of available water for consumption.

Both water pricing strategies are not yet considered by the government to be implemented in the MDB but represent a good alternative to the non-pricing strategies in the eyes of the author.

In summary, those four institutional arrangements apply different approaches but all have the goal to reduce water consumption for the benefit of the environment.

Exact values of environmental benefits are not measurable and are therefore categorised as uncertainties (see Subsection 2.2.1). Therefore, a judgement about the meaningfulness of an institutional arrangement from a normative perspective is difficult. To contribute to a comparison of benefits and costs resulting from the introduction of those WMPs, an economic impact analysis is applied in the following chapter. This analysis concentrates on the estimation of impacts on irrigated crop production and water consumption as a result of different institutional arrangements in the MDB.

5 Effects of Water Management Policies – an Economic Perspective

In previous chapters, different WMPs were introduced, which may help to solve the problem of environmental damages in the MDB resulting from over-consumption of irrigation water. On the one hand, quantitative limiting instruments were discussed, while on the other hand, two different water-pricing strategies were taken into consideration.

These WMPs are suspected to have different impacts on water consumption and irrigated agricultural crop production, which are supposed to be analysed by applying a mathematical modeling approach. To do so, two possible methods were taken into account.

The first method uses a Cobb-Douglas approach that strongly depends on own-price and cross-price elasticities of demand and supply. This model turned out to be incapable of answering research question three due to insufficient available data on elasticities and the sensitivity of the model. It was therefore rejected (see Appendix 7.3 for the conceptual framework and limitations of the Cobb-Douglas model).

As a consequence, the research method was changed. An exploratory mixed method design was applied combining the qualitative method of explorative expert interviews (which was the first phase of the mixed method approach) with the quantitative method of mathematical modeling (which was the second step using results from the first phase). Within this second phase, a linear modeling approach interconnects crop markets and the water market (Subsection 5.1). For the analysis of impacts of the WMPs on irrigated agricultural crop production, the linear Water Integrated Market-Model (WatIM-Model) was developed and different input data was used. The WatIM-Model is a multi-market model observing crop product markets. All selected crop markets are highly dependent on irrigation water, which was crucial for the selection of crop markets for this research.

Considering a comparison of crop markets such as rice, cotton, grapes, vegetables[65] and fruits[66] as performed in the WatIM-Model, observed regions must comprise of all crops to be cultivated. All of these crops are water intensive, but the amount of irrigation water consumed for production and the value produced vary widely. Therefore, crops are divided into water high value and water low value crops. Crops with a ratio of GVIAP to the applied water with less than AU$ 1,500/ML are considered to be water low value crops[67].

Rice and cotton are examples of water low value crops. The GVIAP of cotton was AU$ 673/ML in 2007–08. That means less than AU$ 700 of GVIAP can be derived by an investment of 1 ML of irrigation water when cultivating cotton. The water productivity of rice was even lower with AU$ 274/ML in 2007–08. In contrast, water high value crops such as grapes, fruits and vegetables have a ratio of GVIAP to water applied which is higher than AU$ 1,500/ML (grapes AU$ 3,091/ML, fruits AU$ 4,093/ML and vegetables AU$ 6,901/ML in 2007–08). (Australian Bureau of Statistics, 2010c, Table 6).

Consequently, two water low value crop markets (rice, cotton) and three water high value crop markets (grapes, vegetables, fruits) that are primarily cultivated in the MDB, were chosen for the analysis in this thesis.

As already stated before, these five crop markets account for half of total agricultural water consumption in the MDB (see Subsection 3.2) and are therefore highly relevant water users.

By using the partial equilibrium model framework of the WatIM-Model, different management scenarios can be simulated and economic terms such as costs and benefits can be determined. With this analysis the dependence of crop production on the input factor water (which in turn is strongly influenced by political decisions and strategies) is shown and can be understood.

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[65] Including potatoes, tomatoes, carrots, mushrooms, and onions.

[66] Including mandarins, oranges, apples, pears, bananas, peaches, and strawberries.

[67] Note that the author derives the definition for low/high values not from the GVIAP in proportion to capital investigated (return on investment would be higher) but from the GVIAP in proportion to quantity of used water for production.

5.1 The Linear WatIM-Model

The linear WatIM-Model was developed to answer the third research question by identifying impacts of WMPs on agricultural crop production with the help of scenario analyses.

In the linear partial equilibrium WatIM-Model, water is an input factor for the five agricultural commodity markets rice, cotton, grapes, vegetables, and fruits. In Australia, periodic water scarcities regularly occur with the consequence that water consumption and the GVIAP differ between dry and wet years. For this reason, the WatIM-Model calculates results for dry and wet years differently (see Appendix 7.6). These varying weather conditions are integrated in the static model by implementing dry year (reflecting droughts) and wet year (best conditions for agricultural production, excluding floods) scenarios. For instance, farmers in the MDB suffered from a long-lasting drought from 2001 to 2009 that was followed by Australia's third wettest year on record in 2010. Consequently, the MDB region was without any "normal" state of nature for a decade (90 % drought and 10 % wet). Additionally, droughts are expected to increase in frequency and intensity due to climate change in the future (see Subsection 1). Investigations of the impacts of the WMPs on agriculture are most important for such weather conditions since the impacts for normal state of nature lie in-between dry and wet years. Therefore, it is decisive to observe impacts in extreme situations to be able to weigh the consequences of policy decisions. For these reasons, the WatIM-Model excludes the normal state of nature, and analyses are limited to dry year and wet year scenarios. In the WatIM-Model the implementation of dry year and wet year scenarios is done in a static way rather than dynamic models, which internalise periodic scarcities by using cycles.

Table 4 shows the four examined WMPs that are the non-pricing, non-monetary strategy of the water sharing plan (see Subsection 4.1) and the non-pricing, monetary RtB program (see Subsection 4.2) as well as the two water-pricing strategies of subsidy removing and taxation (see Subsection 4.3). Each scenario analyses the impacts of a WMP separately for dry and wet years. The reference scenario builds the baseline.

Table 4: Scenario analysis with the WatIM-Model

	Water management policies	Category	Goals of the WMP
Reference scenario			
Scenario 1	Water sharing plan (Basin plan)	Non-pricing, non-monetary	Reduction of over-consumption by limiting volume of water availability for irrigation issues (caps)
Scenario 2	RtB program (water right trading)	Non-pricing, monetary	Reduction of over-consumption by decreasing quantity of water rights available to farmers
Scenario 3	Subsidy removing (full cost recovery)	Pricing	Reduction of over-consumption by water price increases by covering water suppliers' costs
Scenario 4	Environment compensating irrigation tax	Pricing	Reduction of over-consumption by water price increases by internalising externalities

The linear WatIM-Model with its economic issues, mathematical formulas, and logic to calculate results was developed by the author. Input data was collected as specified in Subsection 5.1.4. To make it easy to run through different scenarios with varying input factors, a mathematic software program was developed.[68] The output data (e. g. quantity produced, water applied for crop production, revenue, and profit) received from the program is the basis for the scenario analysis.

The next subsection describes the conceptual framework specifying parameters and variables of the model, followed by the description of the optimisation problem in Subsection 5.1.2. The estimation of the inverse demand functions is specified in Part 5.1.3, followed by the determination of data that is used as the parameters for the linear WatIM-Model. Then, assumed levels of irrigation water availabilities are introduced, which is the basis for scenario analyses in Subsection 5.1.7. Since the WatIM-Model is used to analyse impacts of WMPs (that either quantitatively limit water extraction or regulate water prices) on agricultural crop production, Subsection 5.1.6 addresses the determination process, which is applied within the model to gain sustainable crop production levels.

Finally, scenario findings are compared, limitations of the WatIM-Model are pointed out, and conclusions are made.

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[68] The software implementation with the programming language C# is not part of this thesis and was outsourced to a software developer.

5.1.1 Conceptual Framework

The WatIM-Model is a static mathematical model used to find sustainable levels of irrigated crop production and to analyse impacts of different water management policies (WMPs) on irrigated crop production in the MDB. Input data and endogenous variables are on an annual basis.

Endogenous variables

Endogenous variables are derived from the WatIM-Model and are therefore also called solution variables (Chiang and Wainwright, 2005, p. 5 f.). The model distinguishes six endogenous variables for each irrigated crop market m and one variable, which is an aggregate of water consumption of all markets.

Those endogenous variables reflect optimized model results that are calculated assuming the irrigation water availability being unlimited.

- $q_{m\,opt}$: The optimal total annual production of each irrigated crop on market m. [t/year]
- $p_{m\,opt}$: The optimal market price of each irrigated crop on market m. [AU$/t]
- $R_{m\,opt}$: The optimal annual revenue derived from each irrigated crop market m. [AU$/year]
- $\pi_{m\,opt}$: The optimal annual profit derived from each irrigated crop market m. [AU$/year]
- $q_{wdm\,opt}$: The total annual water consumption of each market m under optimal production. [ML/year]
- $c_{m\,opt}$: The optimal total annual cost of each irrigated crop on market m. [AU$/year]
- $\sum_{m=1}^{5} q_{wdm\,opt}$: The sum of total annual water consumption of all five crop markets m under optimal production. [ML/year]

If the volume of needed water for optimal production exceeds defined limits on irrigation water availability (see Subsection 5.1.5), the reducing algorithm (see

Subsection 5.1.6) is applied generating sustainable[69] model results, which are the following endogenous variables:

- $q_{m\ sust}$: The sustainable total annual production of each irrigated crop on market m. [t/year]
- $p_{m\ sust}$: The sustainable market price of each irrigated crop on market m. [AU\$/t]
- $R_{m\ sust}$: The sustainable annual revenue derived from each irrigated crop market m. [AU\$/year]
- $\pi_{m\ sust}$: The sustainable annual profit derived from each irrigated crop market m. [AU\$/year]
- $q_{wdm\ sust}$: The total annual water consumption of each market m under sustainable production. [ML/year]
- $c_{m\ sust}$: The sustainable total annual cost of each irrigated crop on market m. [AU\$/year]
- $\sum_{m=1}^{5} q_{wdm\ sust}$: The sum of total annual water consumption of all five crop markets m under sustainable production. [ML/year]

In this case, the reducing algorithm is applied, and sustainable endogenous variables are used in the scenario analysis in Subsection 5.1.7. If the algorithm is not applied, optimal results are also sustainable (because the volume of water needed for optimal production $\sum_{m=1}^{5} q_{wdm\ opt}$ does not exceed defined limits on irrigation water availability ($q_{w\ avail}$)) and are used for the scenario analyses.

Parameters

Parameters are used to feed the model with data. To achieve the best possible flexibility, all input data are not hard coded (constants) but are provided as parameters when running the model. Those parameters are exogenous data determined by external forces and are given from the outside of the model. (Chiang and Wainwright, 2005, p. 5 f.). The following parameters are kept constant for all model runs:

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[69] The term sustainable refers to water extraction levels, not on the way of using water or the sources of used water.

- q_{wm}: The average volume of water applied for production of one tonne of crop on market m. [ML/t]
- p_{rm}: The average price payed for all other input factors except water (therefore called rest r) for the production of one tonne of crop on market m. [AU\$/t]
- c_{rm}: Rest costs per tonne of crop production are defined by total farm costs (C_m) minus costs for water (C_{wm}) on each crop market m. [AU\$/t]
- a_m *and* b_m: The constants of the inverse demand function are determined in Subsection 5.1.3 and vary between crop markets m. [1]
- γ_m: The calibration factor of each crop market m. [1]
- $\mathrm{x}_{m\ dry}$: The reduction factor of each crop market m used in dry year scenarios. [1]
- $x_{m\ wet}$: The reduction factor of each crop market m used in wet year scenarios. [1]
- $q_{m\ max}$: Maximum annual quantity of crop production in each market m (see Table 4). [t/year]
- $q_{w\ avail\ diff}$: This parameter defines whether the annual quantity of water availability for consumption ($q_{w\ avail}$) refers to a wet or a dry year. This differentiation is the basis for the application of the diverse reduction factors (see $x_{m\ wet}$ and $x_{m\ dry}$ above). [ML/year]
- c_{ws}: Water suppliers' annual costs are relevant for the subsidy removing scenario 3. [AU\$/year]
- $q_{w\ avail\ tax}$: The amount of subject to tax is the quantity of annually available water for consumption ($q_{w\ avail}$) and consequently the basis for differentiation of tax levels. [ML/year]
- $T(q_{w\ avail\ tax})$: Rate of tax applied which are dependent on the levels of annual water availabilities ($q_{w\ avail\ tax}$) which are chosen to degressively differentiate the tax rates. [%]

Besides fixed parameters, the following parameters vary between different model runs:

- $q_{w\ avail}$: Availability of water for irrigation issues for all five crop markets are determined in Subsection 5.1.5. This quantitative limit of water availability represents the maximum water extraction level under which sustainability can be derived. In various WatIM-Model scenarios, water availability changes regarding to the WMP applied. [ML/year]
- p_w: The water price is the same for all crop markets m. The water price is a total paid per ML including prices for water rights and prices for water deliveries but excludes prices for traded water rights. Pricing is volumetric, fixed charges of irrigators without being delivered with water is not included in this analysis. [AU$/ML]

The linear model assumes irrigating water users to be risk neutral and profit maximisers. The WatIM-Model is solved on an annual (water year) basis and is able to process input data and to calculate outputs of one growing season.

For simplifying reasons, each market aggregates all suppliers to one monopoly even though the Australian crop market structure is a bilateral polypoly in reality. Hence, the market price, production quantity, and production costs are average values considered as representative for the whole market sector m.

The same applies for water suppliers and water prices. The model assumes one water supplier who has a quasi-monopolistic position. In reality, many water supply authorities divide their “area of operations” (IPART, 2010, p. 32) that is defined in a legal document such as a State Water Act (ibid., 32) according to regional or geographical characteristics (e. g. the course of a river). A majority of the time, only one water supply authority exists in that area of operations. Hence, not just one water supply monopoly but many monopolies in different regions exist. In this thesis, it is not differentiated between different regions within the MDB, and it is assumed that the MDB is one aggregated region with just one water supplier.

The volume of available water is an aggregate of the seasonally announced volume of water allocations for the whole MDB and is not differentiated by region. The water price is homogenous for all rural consumers and is also not differentiated by region. However, in reality it exists a "large spread of prices around the mean price for a given week [… which is an indicator for] a relatively inefficient market" (National Water Commission, 2011b, p. 86).

Furthermore, the model does not include international trade but uses domestic market supply and assumes consumption price and supply price to be the same.

In the linear WatIM-Model, the demand function of the MDB is assumed to be the same as the Australian demand function. This is due to the assumption that the prices paid for the consumption of irrigated crops, as well as consumption patterns are the same in the MDB and the rest of Australia.

The linear WatIM-Model is a static model and does not simulate changes of time[70] or future projections (as dynamic models do), nor does it focus on external forces that make the equilibrium of a model change (as comparative models do). It is a "snapshot" of markets with quantities and prices without considering frequently changing market equilibria.

5.1.2 The Optimisation Problem

The aggregated supply[71] of each market *m* has the goal to maximise its profit π_m. To find the maximum profit, the objective is to determine the optimal domestic market supply (also called output) q_m.

The maximisation problem for the aggregated crop industry on market *m* is:

$$\max_{q_m} \pi_m (p_m(q_m) q_m - C_m(q_m))$$

with $m = 1, \dots, 5$.

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[70] For the estimation of demand functions, historical time series are used (see Subsection 5.1.3 and Appendix 7.2).

[71] All farms of one type of crop are aggregated to one industry offering their crop products on market *m*.

The profit is derived by revenue R_m minus costs C_m. Revenue is the earning of the aggregated crop industry on market m from output q_m at the price p_m. The price p_m of the good on market m is expressed by the inverse demand function $p_m(q_m)$:

$$p_m(q_m) = a - bq_m$$

with $m = 1, \dots , 5$.

The estimation of the inverse demand function for each market m is specified in Subsection 5.1.3.

The costs C_m that occur for production on each market m are dependent on output q_m. Costs are split into the cost factors water C_{wm} and rest costs C_{rm} on markets m. Accordingly, total costs on market m can be expressed as $C_m = C_{wm} + C_{rm}$.

Costs for water result from the multiplication of the water price p_w for one megalitre (ML) irrigation water by the quantity of water (in ML), which needs to be applied to produce one unit output of q_m on market m. The price payed for other input factors besides water p_{rm} which occur to produce one unit output of q_m on market m equal the rest-costs C_{rm} when multiplying p_{rm} with q_m.

$$C_m(q_m) = q_m(p_w q_{wm} \gamma_m + p_{rm})$$

with $m = 1, \dots , 5$.

The calibration factor γ_m of market m results from the multiplication of the water price p_w by the calibration variable ε_m:

$$\gamma_m = p_w \varepsilon_m$$

with $m = 1, \dots , 5$.

This calibration factor increases the amount of applied irrigation water with increasing water prices. This is realistic because increasing water prices indicate higher water scarcity caused by for example less rainfall or higher temperatures. The result is that more water needs to be applied to cultivate the same quantity of crop output.

Originally, the author also planned to integrate a profit maximisation function of water suppliers in the WatIM-Model. This was rejected since water providers are not able to cover their costs with revenues from water sales in the MDB. They are highly subsidised (see Subsection 3.3.3.2) and sometimes not even sure whether they are profit oriented[72]. Even if the water supplier is a for-profit entity, the goal of profit maximisation of the supplier conflicts with the goal of welfare maximising of the government in cases of natural monopolies. The water prices are not determined by water supply monopolists but from independent institutions and are fixed for a 4 to 5 year period of time. The maximum profit the supplier is allowed to gain is predefined by those independent institutions. Those profits must exceed opportunity costs to prevent deficits (Bös, 1994, p. 274).

5.1.3 Estimating Inverse Demand Functions

For the estimation of inverse demand functions, the two-stage-least-squares (TSLS)-method was used.

The ordinary-least-squares (OLS)-method did not work because the variables are related to the explanatory variable. The problem of endogeneity occurs because price and quantity are in the optimum of the economic theory, an equilibrium price and an equilibrium quantity, and therefore describe supply and demand at the same time.

The endogenous variables have to be replaced by “instrument” variables which are not correlated to exogenous variables but which correlate with the replaced variables. Hence, replaced variables are now called “instruments”.

A TSLS regression analysis was carried out in two stages[73] by using historical data sets (see Appendix 7.2):

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[72] For instance, the New South Wales bulk water operator stated: “State Water has applied its judgment in assessing whether it meets the definition of a for-profit or not-for-profit entity for the purposes of the accounting standards. State Water has concluded that the business is a for-profit entity, taking into account the objectives of corporatisation, the governance framework applied, the application of pricing principles to achieve full cost recovery on a commercially sustainable basis, and the registration of State Water Corporation under the National Tax Equivalent Regime.” (State Water Corporation, 2012, p. 86).

[73] According to Kmenta, 1986, pp. 681–89 and with the help of two online-tutorials (Burkey Academy, 2010 and pspollard1, 2010).

The first stage of the TSLS analysis was to regress the endogenous variable price p_m for the good on market m using the exogenous variables *average annual earnings* (of total Australian population) E, *final consumption expenditures* (of total Australian population) C, *time in years* (e.g. 16, from year 1995–2010) A to gain predicted $\hat{p}_m$.

Overview of variables used in stage 1:
Endogenous variable: p_m
Exogenous variables: E, C, A
Instrument: predicted: $\hat{p}_m$

In stage 1 of the TSLS-method, the endogenous part of p_m was removed and only the systematic part of p_m was used, which is related to E, C, and A. Hence, instead of using the real prices when estimating the demand equation, the predicted price $\hat{p}_m$ was used.

The second stage was to regress the output q_m on the exogenous variables E and predicted $\hat{p}_m$ from stage 1.

Overview of variables used in stage 2:
Endogenous variable: q_m
Exogenous variables: E, predicted $\hat{p}_m$
Instrument: predicted $\hat{q}_m$

In stage 2 of the TSLS-method, the endogenous part of q_m is removed and only the systematic part of q_m that is related to E and $\hat{p}_m$ was used. Instead of using the real output when estimating the demand equation, the predicted output $\hat{q}_m$ was used.

After these two steps of regression, the equation for the predicted output of rice for example is: $\hat{q}_r = 173{,}633 - 1{,}438\ \hat{p}_r + 0.917\ E$

To reduce unknown variables to one, E was substituted by the average annual earnings (of total Australian population) from 1995–2010.

As a result of the TSLS-method, the predicted demand equation for rice (see Figure 12) during this time period and the dataset (see Subsection 5.1.4) is:

$\hat{q}_r(\hat{p}_r) = -1,438\hat{p}_r + 825,906$

Figure 12 illustrates the preliminary demand function of rice as a result of the TSLS-method.

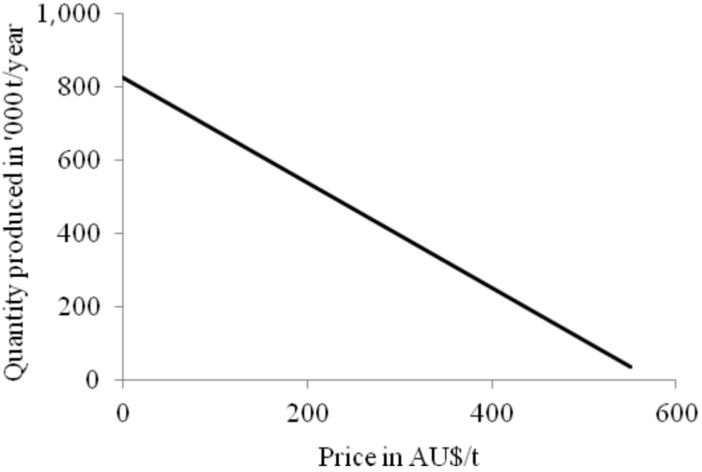

Figure 12: Preliminary demand function for rice as result of TSLS-method

This demand function for rice had to be transformed into an inverse demand function (see Figure 13):

$\hat{p}_r(\hat{q}_r) = -0.0007\hat{q}_r + 574$

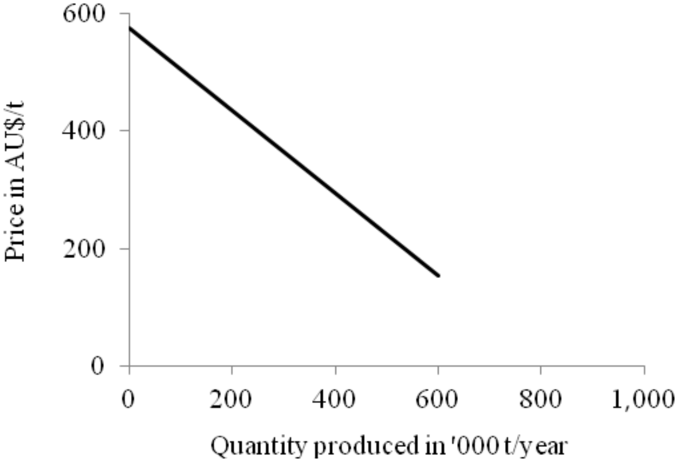

Figure 13: Preliminary inverse demand function for rice as result of TSLS-method

The same procedure was carried out for cotton, grapes, vegetables, and fruits. The results are the following preliminary inverse demand functions:

$\hat{p}_c(\hat{q}_c) = -0.0016\hat{q}_c + 3,747$ for cotton

$\hat{p}_g(\hat{q}_g) = -0.0002\hat{q}_g + 547$ for grapes

$\hat{p}_v(\hat{q}_v) = -0.0003\hat{q}_v + 1,356$ for vegetables

$\hat{p}_f(\hat{q}_f) = -0.0002\hat{q}_f + 3,112$ for fruits

The plausibility of the inverse demand functions was tested by comparing preliminary results of optimal annual production based on inverse demand functions with real observed data (see Figure 14). This was carried out for a dry year (2007–08) when the average water price for irrigation water was high. The water price was assumed to be AU$ 180/ML in average[74] for the dry year comparison.

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[74] Price for water allocations was for instance higher than AU$ 500/ML in the irrigation region of Murrumbidgee in the dry year 2007–08 (National Water Commission, 2011f, p. 35).

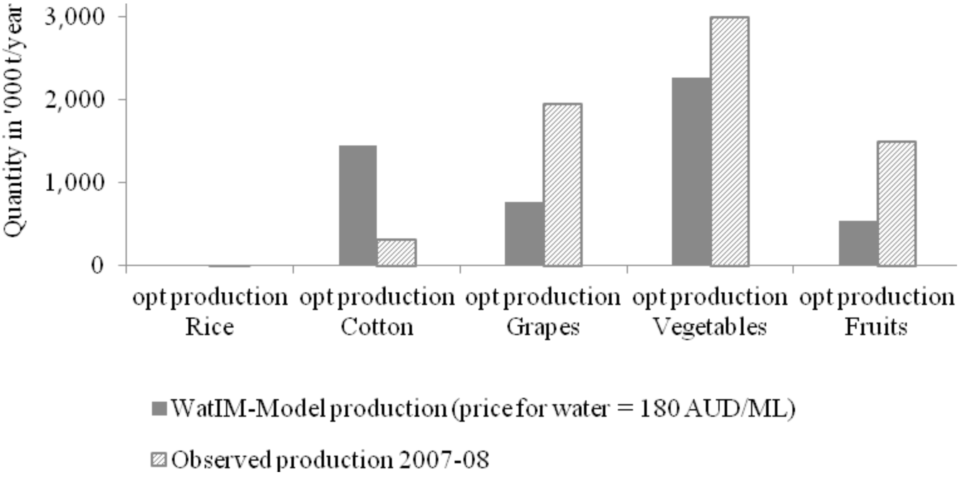

Figure 14: Optimal annual production comparison (dry year) (own illustration; data for observed production ABARES, 2011; FAOSTAT, 2010b).

Figure 14 illustrates that the WatIM-Model over-calculated cotton production and under-calculated grape, vegetable, and fruit production during dry years.

Similar mismatches can be obtained when observing the results for a wet year, when the water price is assumed to be AU$ 60/ML in average. Figure 15 shows that productions are to some extent severely (e. g. in the case of rice production) underestimated by the WatIM-Model. Only the simulated cotton production is close to real cotton production.

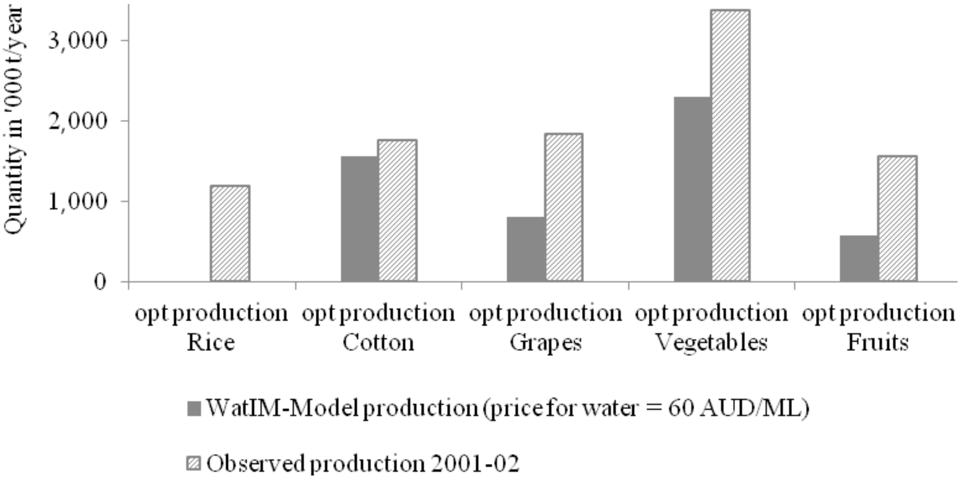

Figure 15: Optimal annual production comparison (wet year) (own illustration; data for observed production from ABARES, 2011 and FAOSTAT, 2010b).

Both illustrations show that results from the WatIM-Model were not close to the real observed production. This led to the conclusion that the inverse demand functions – on which basis the optimisation took part in the WatIM-Model – had to be adapted.

The adaption of the model was undertaken by applying the approximation method and manipulating the inverse demand function. The adapted inverse demand functions are outlined in the overview below:

Preliminary inverse demand functions

Rice $p_r(q_r) = -0.0007q_r + 574$

Cotton $p_c(q_c) = -0.0007q_c + 2{,}965$

Grapes $p_g(q_g) = -0.0006q_g + 1{,}245$

Vegetables $p_v(q_v) = -0.0003q_v + 1{,}525$

Fruits $p_f(q_f) = -0.0008q_f + 1{,}978$

Adapted inverse demand functions

Rice $p_r(q_r) = -0.0006q_r + 2{,}974$

Cotton $p_c(q_c) = -0.0007q_c + 3{,}365$

Grapes $p_g(q_g) = -0.0002q_g + 1{,}115$

Vegetables $p_v(q_v) = -0.0003q_v + 2{,}115$

Fruits $p_f(q_f) = -0.0008q_f + 3{,}512$

The adapted inverse demand function for example for rice is less elastic than the preliminary inverse demand function and the prohibitive price of 2,974 AU$/t is much higher than before (see Figure 16).

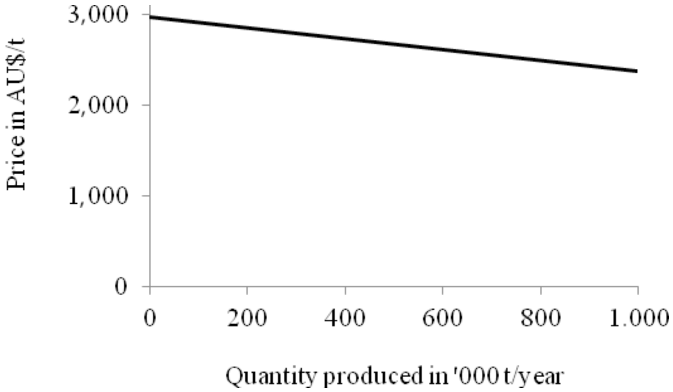

Figure 16: Adapted inverse demand function rice

Additionally, to the adaption of the inverse demand function, the adjustment implied to change the calibration variable ε_m from 0 to:

$\varepsilon_r = 0.05$ for the rice market

$\varepsilon_c = 0.05$ for the cotton market

$\varepsilon_g = 0.015$ for the grape market

$\varepsilon_v = 0.02$ for the vegetable market

$\varepsilon_f = 0.01$ for the fruit market.

With the adaptions of the inverse demand functions and the introduction of the calibration variables, the results of the WatIM-Model are very close to real observed data as shown in Figure 17 for a dry year and Figure 18 for a wet year.

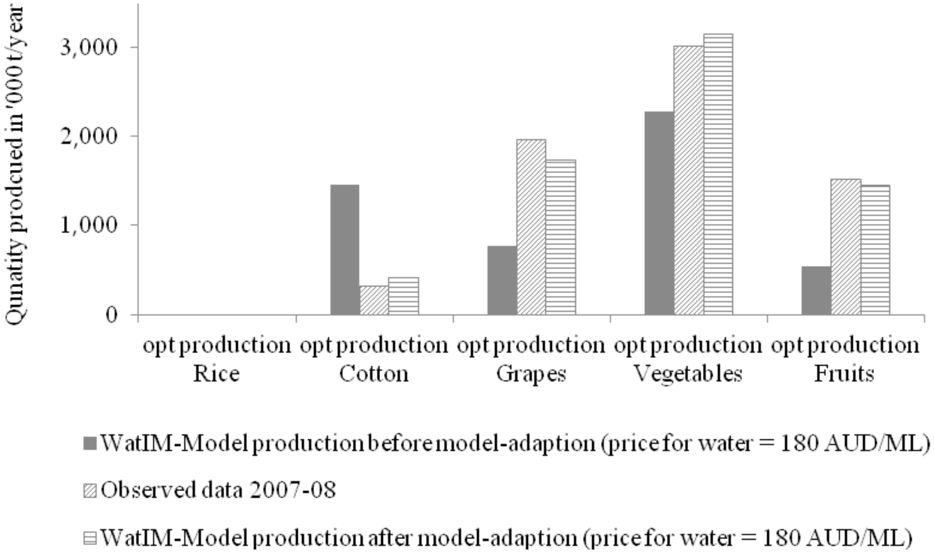

Figure 17: Optimal annual production – before and after model-adaption (dry year) (own illustration, data for observed production from ABARES, 2011 and FAOSTAT, 2010b).

As already pointed out in Subsection 1.3.2, a mathematical model is the abstraction of reality. This abstraction should be as close to reality as possible to enable the researcher to reconstruct realities' complexity of relationships and interdependencies. When the model outputs are close to real observed data, it can be assumed that the model is capable of reflecting reality under the assumptions made. On this basis, external "shocks" can then change initial values and impacts can be analysed.

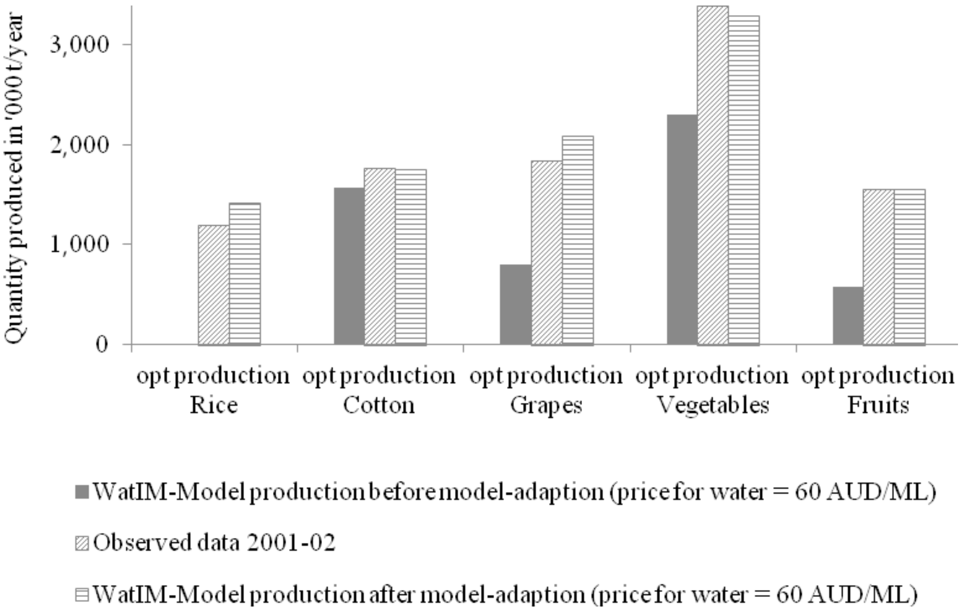

Figure 18: Optimal annual production – before and after model-adaption (wet year) (own illustration, data for observed production from ABARES, 2011 and FAOSTAT, 2010b).

The WatIM-Model is used to analyse impacts of different WMPs, which can be seen as external shocks to manipulate water availability for irrigation issues or the water price. Impacts on irrigated agricultural production are simulated with the WatIM-Model and provide knowledge about possible economic effects. It is important to reflect reality in a mathematical model as precisely as possible. This is the reason the procedure was used to estimate inverse demand functions in this section.

5.1.4 Data for the Linear WatIM-Model Approach

To evaluate the different effects of the WMPs on water high and water low value crop industries in the MDB, data is required for rice, cotton, grapes, vegetables and fruits as well as for the water market. The area of observation in the WatIM-Model is the MDB.

At the time of collecting the input data for the WatIM-Model, the most recent data available was up to 2010–11. Therefore no data after this time could be taken into consideration.

For quantities q_m and prices p_m of crop consumption, data from the ABARES rural commodities statistics and the Food and Agriculture Organization of the United Nations (FAO) statistic of food balance sheets (ABARES, 2011; FAOSTAT, 2010b) for the years 1994–95 to 2009–10 are used.

Data on water use for rice, cotton, grapes, vegetables, and fruits production in the MDB was collected from the ABS statistics in "Water and the Murray-Darling Basin – A Statistical Profile, 2001–01 to 2005–06" (Australian Bureau of Statistics, 2008b), "Murray-Darling Basin – Gross Value of Irrigated Agricultural Production, 2000–01 to 2008–09" (Australian Bureau of Statistics, 2010d), and "Gross Value of Irrigated Agricultural Production, 2000–01 to 2009–10" (Australian Bureau of Statistics, 2011b).

Data on the Australian water use for production of the five observed crops was used from the ABS statistics in "Water use on Australian farms 2008–09" (Australian Bureau of Statistics, 2010a and 2010f), "Gross Value of Irrigated Agricultural Production, 2000–01 to 2009–10" (Australian Bureau of Statistics, 2011b), and "Australia – Gross Value of Irrigated Agricultural Production, 2000–01 to 2007–08" (Australian Bureau of Statistics, 2010c).

For the determination of the average volume of water applied for the production of one tonne of crop data from ABARES, FAOSTAT and ABS are used including data on the volume of water used for production (in ML/year) and the annual crop production (t/year) for the years 2002–03 to 2007–08 (ABARES, 2011; FAOSTAT, 2010b; Australian Bureau of Statistics, 2010c). The average volumes of water applied for production of one tonne of crop for the market m are the following:

$q_{wr} = 1.49$ (ML/t) for the rice market
$q_{wc} = 1.29$ (ML/t) for the cotton market
$q_{wg} = 0.32$ (ML/t) for the grape market

$q_{wv} = 0.14$ (ML/t)	for the vegetable market
$q_{wf} = 0.53$ (ML/t)	for the fruit market

Data on GVIAP was used from ABS's statistics for the years 2005–06 to 2009–10 (Australian Bureau of Statistics, 2010d; Australian Bureau of Statistics, 2011b) which cover the area of the MDB.

For the determination of the average price (p_{rm}) paid for all other input factors except water (therefore called rest *r*) and for the production of one tonne of crop on market *m*, ABARES provided data about total cash costs per farm, water costs per farm, and population (refers to the number of farms in each category) (see Appendix 7.5) on request. This data is used to calculate the rest costs which arise to produce one tonne of crop on market *m*. Additionally, data on crop production (q_m) from ABARES' rural commodities statistics and the FAO statistic of food balance sheets (ABARES, 2011; FAOSTAT, 2010b) for the years 2006–07 to 2010–11 is used.

$p_{rr} = 1{,}017$ AU\$/t	for the rice market
$p_{rc} = 693$ AU\$/t	for the cotton market
$p_{rg} = 267$ AU\$/t	for the grape market
$p_{rv} = 136$ AU\$/t	for the vegetable market
$p_{rf} = 1{,}017$ AU\$/t	for the fruit market.

Although data regarding crop demand was available for Australia as a whole, it was not available for the MDB region. Therefore, it is assumed that the demand structure and individual consumer preferences are the same for both the MDB and the whole of Australia. For the estimation of the inverse demand functions, historical data from 1994–95 to 2009–10 for the whole of Australia are used for the TSLS-analysis (see Appendix 7.2).

The *average annual earnings E* of total Australian population (in AU$ million/year) was projected from the average weekly earnings per person provided by the Australian Bureau of Statistics (Australian Bureau of Statistics, 2011a). The *final consumption expenditures C* of total Australian population (in AU$ million/year) were projected from the final consumption expenditures per capita made available by the ABS's Australian National Accounts (Australian Bureau of Statistics, 2012a).

5.1.5 Determination of Water Availability for WatIM-Model Scenarios

Water availability, which is announced by governments to be usable for farmers, is influenced by the total available water in resource systems, weather conditions, intensity of previous water consumption, water storage levels, forecast about seasonal water availabilities (National Water Commission, 2013a, p. 12), and political objectives.

The volume of water consumed by irrigated crop farmers in the MDB varies frequently. The water consumption in the MDB in 2007–08 for rice, cotton, grape, vegetable, and fruit farms was 1,223 GL in total, which was a very dry year (Australian Bureau of Statistics, 2010d). In contrast, during the wet year[75] of 2001–02 water consumption was about 6,024 GL in the MDB for the above mentioned crops (Australian Bureau of Statistics, 2008b).[76] The difference in the consumed volume of the irrigation water by these five crop farms in the MDB was nearly 4 million ML between both years. High variability can also be observed for the whole agricultural industry and for the whole of Australia (Table 5). For this reason, it is differenciated between dry and wet year scenarios in the WatIM-Model to be able to compare the development of crop production and water consumption. Once reference values are provided, impacts and consequences of the changing conditions for farmers, and the necessary extent of adaption measures can be estimated.

Available water used for the scenarios in the WatIM-Model is based on historical agricultural water consumption for the five crop-markets in the MDB, which is highlighted in Table 5 and is approximately half of the total annual water diversion of all users (e. g. other industries and households). Hence, the observed water consumption of 1,233 GL in the water year 2007–08 is the reference water availability for dry years and the observed volume of 6,024 L of water consumed

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[75] The author decided to choose the year 2000–01, which was the last wet year before the long-lasting drought, which lasted from 2001 to 2009. Since 2009–10 was characterized by devastating floods, which led to immense production losses, data of that year is not suitable as reference data for a wet year.

[76] Those quantities consumed are not differentiated according to the source of water. Hence, it is not differentiated between surface and groundwater in this thesis.

in 2000–01, is used for the reference wet year scenario. Available water ($q_{w\ avail}$) in the WatIM-Model under WMPs is assumed to be the following:

Table 5: Agricultural water consumption in Australia and the MDB

	Dry year in GL	Wet year in GL
Total water diversion (all users) MDB	~ 5,000	~ 12,000
Agricultural water consumption Australia	6,285	16,660
Agricultural water consumption MDB	3,142	10,516
Agricultural water consumption Australia (5 markets)	1,843	6,947
Agricultural water consumption MDB (5 markets) =initial condition	**1,223**	**6,024**

Source: own illustration, data from Murray-Darling Basin Authority, 2011a, p. 8 and Australian Bureau of Statistics, 2008b, 2010e, 2010d and Australian Bureau of Statistics, 2004.

The water sharing plan (see Subsection 4.1) may cut total available water for the Basin by 4,000 GL[77] (for all users), which is supposed to be a long-term average. Since water consumption of the five markets *m* is about half of total annual water diversion of all users, the restriction would affect agricultural industry in the MDB by 2,000 GL/year on average. As Figure 10 shows, there are four possible approaches to implement the water sharing plan. Since it is not clear which one is going to be implemented by the MDBA, for the analysis in this thesis approach "a" is chosen. This means that the equal volume of water is reduced during wet and dry periods. Therefore, available water is not 1,223 GL (initial condition) but 0 GL in the dry year water sharing plan scenario. The same procedure applies for the wet year water sharing plan scenario in which available water is assumed to be 4,024 GL in the WatIM-Model (see Table 6).

In the course of the RtB program (see Subsection 4.2), the Australian government buys water access entitlements from farmers and therefore reduces the volume of available water for agricultural consumption. 1,326 GL of water access enti-

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[77] This is the third and most radical scenario analysed by the MDBA.

tlements were purchased by the Australian government between 2007–08 and 2011–12 (National Water Commission, 2013a, p. 63). The volume of water allocations depend on seasonal state government announcements and often the whole volume of water access entitlements is not allocated with water. Therefore, it is assumed that water availability for irrigation is 1,000 GL less in the RtB program scenario than in the reference scenario. Therefore available consumption water is 223 GL for the dry year scenario and 5,024 GL for the wet year scenario.

The two water pricing strategies do not reduce the volume of available consumption water. Therefore the volume of available water is the same as in the initial condition, which is 1,223 GL for the dry year scenario and 6,024 GL for the wet year scenario.

Table 6: Available water for consumption for the five crop markets (rice, cotton, grapes, vegetables, and fruits) under WMPs in the MDB

Water management policies	**Available water for consumption in dry years**	**Available water for consumption in wet years**
Water sharing plan	0 GL/year (2,000 GL/year less than initial condition)	4,024 GL/year (2,000 GL/year less than initial condition)
RtB program	223 GL/year (1,000 GL/year less than initial condition)	5,024 GL/year (1,000 GL/year less than initial condition)
Price strategy (Subsidy removing)	1,223 GL/year (no quantitative change of available water)	6,024 GL/year (no quantitative change of available water)
Price strategy (Environment compensating irrigation tax)	1,223 GL/year (no quantitative change of available water)	6,024 GL/year (no quantitative change of available water)

The following subsection clarifies the relevance of the above determined water availability for consumption ($q_{w\ avail}$) for the scenario analyses in the WatIM-Model.

5.1.6 Determining Sustainable Production Levels

This subsection explains the determination process, which is applied within the WatIM-Model to gain sustainable crop production levels.

The model interconnects all five product markets (rice, cotton, grapes, vegetables and fruits) on the water market. The first step of calculation is to determine the optimal output of all of these crop markets q_m without restricting water availability by applying the maximisation problem that is described in Subsection 5.1.2.

Without any water limitation, optimal production of the five crop markets would be the following:

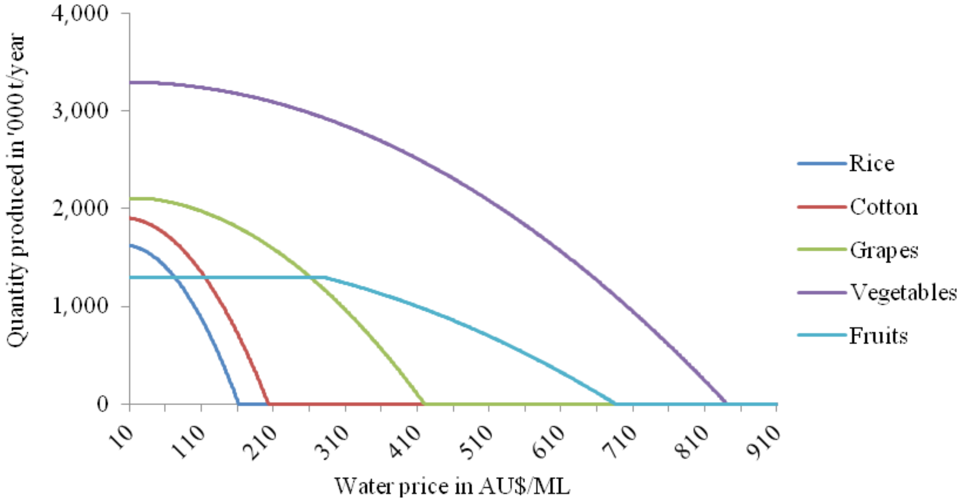

Figure 19: Optimal crop production

Figure 19 shows that optimal crop production decreases with rising water prices since production costs increase. At water prices between AU$ 10/ML and AU$ 40/ML, grape production is limited to an output of 2,100,000 t/year and fruit production is restricted to a production of 1,300,000 t/year between a water price of AU$ 10/ML and AU$ 280/ML. The reason for the limitation of the production possibilities will be clarified later in this section (see Table 7).

By multiplying the optimal output q_m by the average volume of water applied for the production of one tonne of crop (q_{wm}) (see Subsection 5.1.4), the water consumption q_{wdm} of each market m is calculated.

$$q_{wdm} = q_m q_{wm}$$

Figure 20 shows the water consumption under optimal production including total water consumption for all five crop markets.

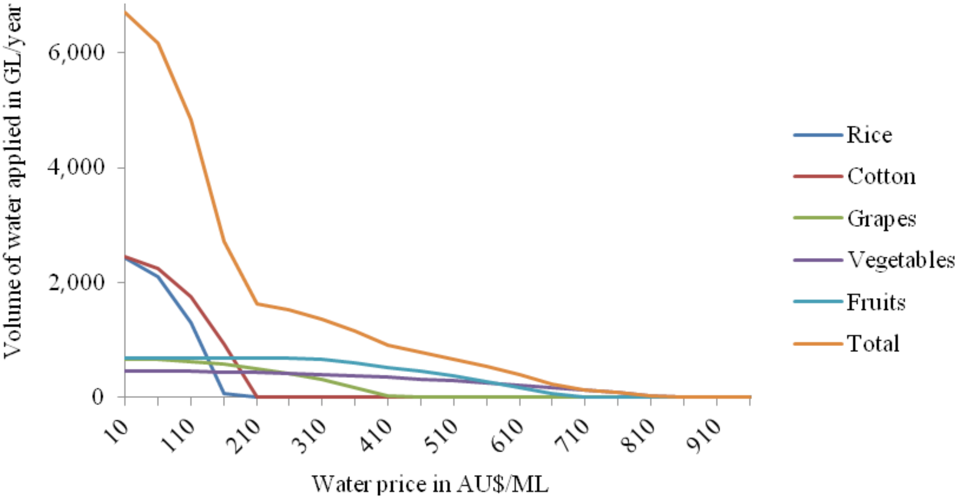

Figure 20: Water consumption under optimal production

Total water consumption of all five markets ($q_{wd\ total}$) is the sum of water consumption of all markets m:

$$q_{wd\,total} = \sum_{m=1}^{5} q_{wdm}$$

The next step in the WatIM-Model is to figure out whether total water consumption under optimal production would exceed the volume of available consumption water.

Over-consumption of water led to environmental problems in the MDB. To solve these problems, the Australian government intervenes in markets with the goal to reduce the available volume of water in the case of the non-pricing policy of water sharing planning. Accordingly, in the WatIM-Model examination process, it is determined how much water has to be reduced from water consumption under optimal production, to gain a sustainable water extraction level[78] considering the best economic benefit from agricultural production. For this reason, a water reducing algorithm was developed.

Water reducing algorithm

Based on the volume of consumption water needed for optimal production and the total volume of available water, the amount of potentially over-consumed water can be determined.

The WatIM-Model compares total water consumption ($q_{wd\ total}$) that is needed to cultivate the quantity of crops under optimal production, with available water resources ($q_{w\ avail}$) as illustrated in Figure 21. If $q_{wd\ total}$ exceeds $q_{w\ avail}$, optimal production of all crops is not possible. In this case the reducing algorithm is applied to reduce the quantity of irrigation water to the maximal available water.

Since optimal crop production (and therefore water consumption) is highest when water prices are at their lowest, the difference between total water consumption under optimal production ($q_{wd\ total}$) and available water ($q_{w\ avail}$) decreases with rising water prices[79]. Consequently, less water needs to be reduced from water consumption under optimal production when water prices are higher.

The total volume of water that needs to be reduced ($q_{w\ red}$) is calculated by total water consumption of all markets ($q_{wd\ total}$) minus the amount of water, which is available $q_{w\ avail}$:

$$q_{w\ red} = q_{wd\ total} - q_{w\ avail}$$

The amount of water, which needs to be reduced on each market m ($q_{wm\ red}$) equals the sum of the total volume of water that needs to be reduced ($q_{w\ red}$):

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[78] That differs according to the WMP's definition of water availability level (see Subsection 5.1.5).

[79] For the WatIM-Model scenario analyses, water prices are not differentiated between prices for water rights and water prices for water deliveries. The water price is a total paid per ML including prices for water rights and prices for water deliveries. Pricing is volumetric, fixed charges of irrigators without being delivered with water is not included in this analysis.

$$q_{w\,red} = \sum_{m=1}^{5} q_{wm\,red}$$

To calculate the necessary reduction of water consumption on each market *m*, several mechanisms are used in order to allocate water fairly and efficiently. To approach fair water distribution and reflect mechanisms of the market economy, more water is taken from less water efficient water users.

For this reason, a reduction factor (x_m) is introduced for each market, reflecting water efficiency in combination with water consumption under optimal production.

The reduction factor (x_m) results from the ratio of the percentage of the volume of water applied for crop production on market *m* to total water consumption ($\frac{100\,q_{wdm}}{q_{wd\,total}}$) to the ratio of the percentage of GVIAP of market *m* to the sum of all GVIAP of all markets *m* ($\frac{100\,GVIAP_m}{\sum_{m=1}^{5} GVIAP_m}$) (see Appendix 7.6):

$$x_m = \frac{100\,q_{wmd}}{q_{wd\,total}} \left(\frac{100\,GVIAP_m}{\sum_{m=1}^{5} GVIAP_m}\right)^{-1}$$

The reduction factor (x_m) is differentiated between a dry year (which starts at a water availability of 2,500 GL/year in the MDB) and a wet year (when water availability is less than 2,500 GL/year in the MDB) (see Appendix 7.6).

By multiplying the reduction factor (x_m) by the volume of water consumed (under optimal production) on market *m* (q_{wdm}) a transition factor is introduced:

$$y_m = x_m q_{wdm}$$

The volume of water that needs to be reduced in market *m* ($q_{wm\,red}$) results from the total volume that needs to be reduced ($q_{wd\,red}$) divided by the sum of transition factors of all markets *m* ($\sum_{m=1}^{5} y_m$) multiplied by the transition factor of market *m* (y_m):

$$q_{wm\,red} = \frac{q_{wd\,red}}{\sum_{m=1}^{5}} y_m$$

The volume of water that needs to be reduced in market m ($q_{wm\,red}$) is determined on the basis of optimal production that does not consider available water resources. Since there are market independent elements in the formula for the calculation of $q_{wm\,red}$, it could be the case that $q_{wm\,red}$ is higher than water consumption on market m under optimal production. Since the amount to be reduced cannot be higher than the actual water consumption under optimal production, the volume of water that needs to be reduced on that market is set to the volume of water consumption.

If on any of the considered markets the volume of water that needs to be reduced is set to the volume of water consumption, the reducing algorithm starts over without these markets to calculate the volume of water that needs to be reduced for the remaining markets as illustrated in Figure 21.

The outcome of the reducing algorithm is the volume of water that needs to be reduced on each market m. Consequently, the new volume of water for the consumption of each market m is calculated. This can be zero if the volume of water that needs to be reduced on market m equals the volume of water consumption of market m under optimal production.

Based on the new volume of available consumption water, the new production quantities can be determined (which depends on water availability and might not equal optimal production under profit maximisation).

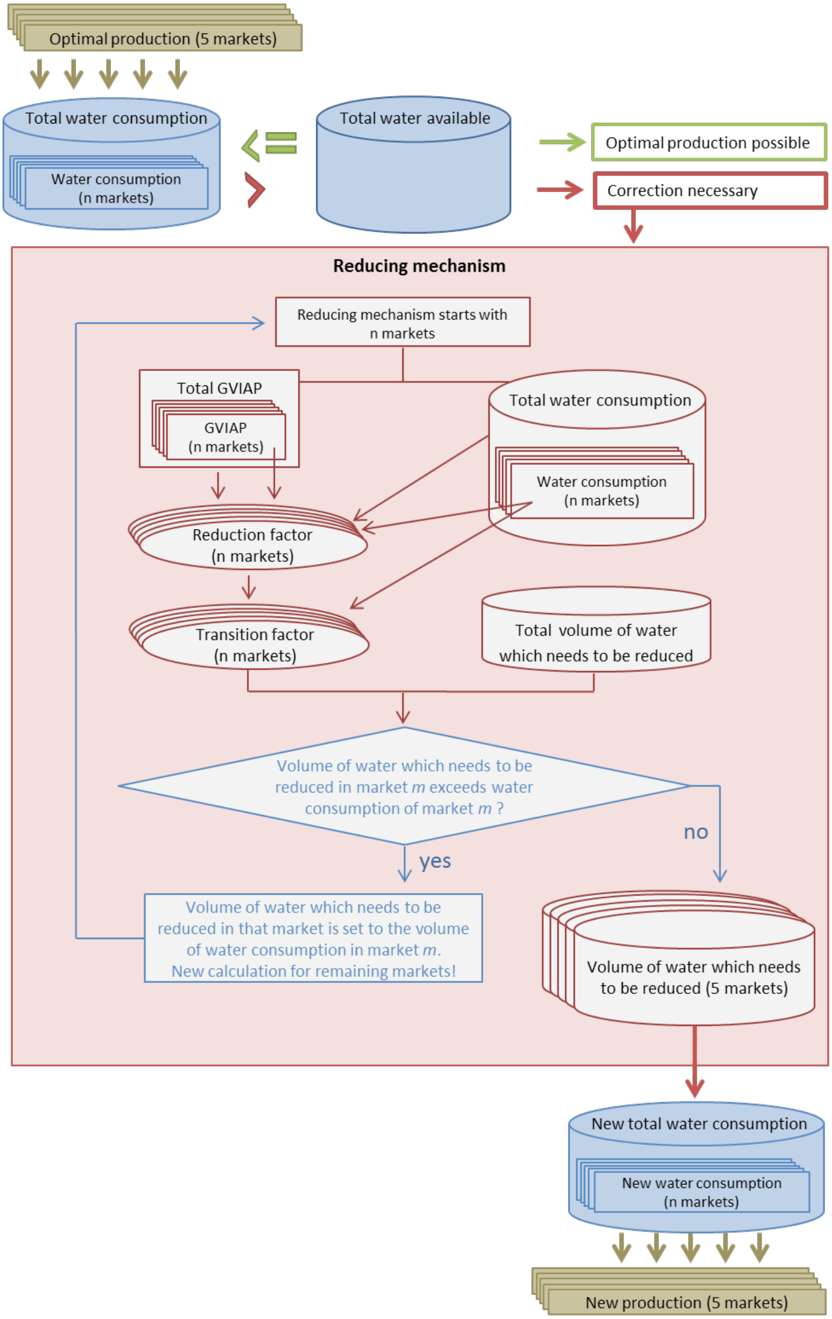

Figure 21: Reducing algorithm of the WatIM-Model

Figure 22 illustrates the difference between optimal and sustainable crop production which are exemplified in the cases of rice and cotton.

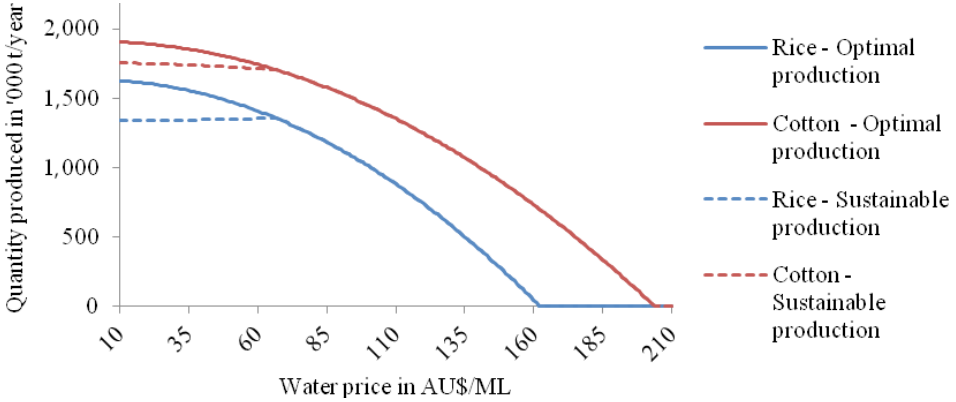

Figure 22: Optimal and sustainable rice and cotton production (reference scenario – wet year)

This example clearly shows the correction of the output by the reducing algorithm until a water price of AU$ 66/ML. With the reducing algorithm, sustainable[80] rice production is for example 300,000 t/year smaller than at optimal production at the water price of AU$ 10/ML when available water is limited to 6,024 GL/year (grape, fruit, and vegetable production and the corresponding water consumption are included in the calculation but not illustrated in Figure 22). If the water price is higher than AU$ 66/ML, water consumption under optimal production does not exceed available water and the reducing algorithm does not have to be applied. Therefore, the dotted line equals the solid line starting at a water price of AU$ 67/ML.

On the basis of sustainable water consumption on market *m* ($q_{wdm\ sust}$), sustainable quantity produced on market *m* ($q_{m\ sust}$) can be determined (which depends on water availability and is not necessarily equal to optimal production under profit maximisation).

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[80] Sustainable regarding the volume of water extractions.

Additionally the WatIM-Model limits possible crop production to a maximum $q_{m\ max}$ (see Table 7), which is defined by the maximal observed annual production in the MDB from 2000 to 2011[81].

$$q_{m\ opt} \geq q_{m\ sust} \leq q_{m\ max}$$

Since water availability for irrigation will be even less in the future due to policy decisions and climate change (see Subsection 1), $q_{m\ max}$ is chosen to be no higher than the maximum quantities produced from 2000 to 2011. The author is aware that besides irrigation water availability, other factors such as technological change, soil consistencies, climate differences, and varying topography of the landscape have an influence on the quantities of crops produced, but these are not included in the consideration.

Table 7: Maximal production in the WatIM-Model

Crop	Max production in t/year historical data (year)		Max production in t/year in the WatIM-Model
Rice	1,643,000	(2000–01)	$q_{r\ max} \leq 1{,}700{,}000$
Cotton	2,167,045	(2010–11)	$q_{c\ max} \leq 2{,}200{,}000$
Grapes	2,093,700	(2003–04)	$q_{g\ max} \leq 2{,}100{,}000$
Vegetables	3,382,629	(2001–02)	$q_{v\ max} \leq 3{,}400{,}000$
Fruits	1,238,272	(2007–08)	$q_{f\ max} \leq 1{,}300{,}000$

Source: own illustration, data from ABARES, 2011 and FAOSTAT, 2010b.

In the linear WatIM-Model, crop markets are connected with each other in the water market. Therefore, the volume of water that needs to be reduced in market m ($q_{wm\ red}$) is reliant on the total quantity of water that needs to be reduced, as well as the market-specific reduction factor. $q_{wm\ red}$ also depends on the other crop markets, with their individual water consumption under optimal production.

The relationship between crop markets can clearly be observed when the crop production and water consumption of one market decreases while it increases on another crop market at the same time (for instance see Figure 35). In cases of a strong decrease of optimal production in one crop market, at a certain water price due to rising production costs, water consumption drops as well. There-

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[81] Numbers are rounded up to allow minimal production increases.

fore, suddenly more water is available for the other crop markets. Although optimal production slightly decreases with increasing water prices in the other markets, sustainable crop production does not necessarily have to be decreased since less water needs to be reduced than at lower water price levels for these other markets. This effect is the re-allocation of water between observed irrigated crop industries.[82]

The reducing algorithm of the WatIM-Model is highly important for the determination of sustainable crop production when there is less water available than needed for optimal production. Based on the above explained determination processes, the following subsection analyses the impact of the WMPs on crop production and takes sustainable water consumption levels into consideration.

5.1.7 Scenario Analysis – Non-Pricing Strategies

The linear WatIM-Model has the goal to analyse the impact of the WMPs on irrigated agricultural crop production. Firstly, the two non-pricing strategies, which reduce the volume of available consumption water are examined in this subsection. In order to be able to compare impacts of WMPs, a reference scenario is introduced in Subsection 5.1.7.1 providing reference data for analysing non-pricing strategies. Scenario 1 applies the WMP of water sharing planning in Subsection 5.1.7.2 and Scenario 2 simulates the impact of the RtB program in Subsection 5.1.7.3. Both scenarios provided data on the changing agricultural crop production and water consumption.

Due to different weather conditions and a high variability of water availability, production varies significantly in Australia. Therefore, each scenario analysis takes dry and wet year conditions into account.

Within each scenario analysis (based on different levels of available water), it is assumed that the only changing variable is the water price[83]. Any other political

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[82] Note: this must not be the case in reality since water could be sold on the water market when water prices clearly increase or a commodity change to other than the five crops observed in the WatIM-Model is made. These opportunities cannot be represented in the WatIM-Model yet.

[83] The WatIM-Model runs for this thesis consider water price increases from AU$ 10/ML until AU$ 1,000/ML in increments of AU$ 10 (with the exception of the subsidy removing

strategy or factors such as on-farm production costs, technological change etc. are supposed to be the same in the scenario analyses.

5.1.7.1 Reference Scenario

The reference scenario is used to provide reference data for the two non-pricing strategies of the water sharing plan and the RtB program. In this scenario, no WMP is applied. Water consumption is limited to a volume of 6,024 GL/year for the wet year scenario and 1,223 GL/year for the dry year scenario.

Wet year – Reference scenario

The sustainable water price minimum is the price where water consumption under optimal production equals the volume of water availability. Since water consumption under optimal crop production would exceed the maximum cap when the water price is below AU$ 70/ML, the reducing algorithm has to be applied until this price level. During wet years, AU$ 70/ML would be an appropriate price when reflecting water availability. Figure 23 illustrates water consumption that does not exceed the volume of available water of 6,024 GL/year since the reducing algorithm was applied.

Since water consumption of grapes, fruits, and vegetables is comparatively low and water productivity (ratio of the percentage of water applied and the percentage of GVIAP) is higher than that of rice and cotton, the effect of the reducing algorithm is negligible for grapes, fruits, and vegetables.

As illustrated in Figure 23, the cotton industry uses the most irrigation water for production followed by rice until a water price of AU$ 130/ML. Water consumption of water low value crops (rice and cotton) is much higher when prices are lower. Hence, water low value crops are more water price elastic than crops with higher water efficiency. For this reason, both water low value crop markets react strongest to water price increases.

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scenario 3). As a result there might be slight discrepancies concerning statements about for instance sustainable water prices and the maximum price until which crop production is possible. Smaller increments are possible with the WatIM-Model but were not chosen to limit quantity of data.

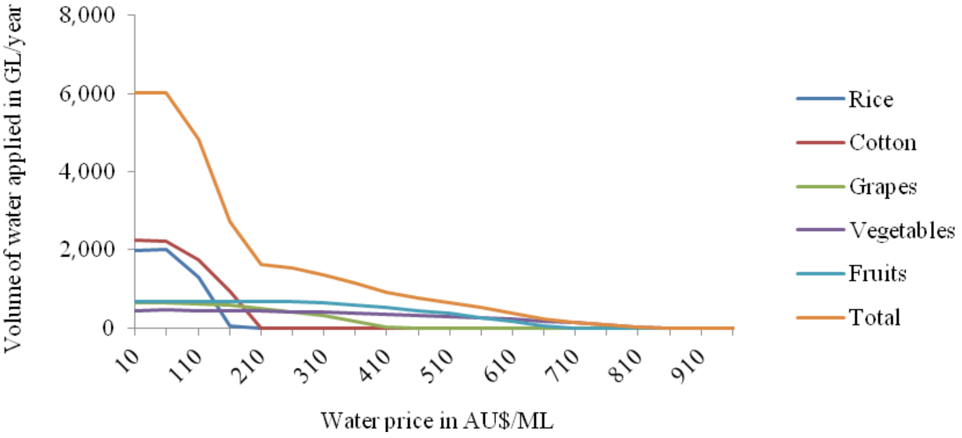

Figure 23: Water consumption with reducing algorithm (reference scenario – wet year)

The ratio of water consumption and the quantity produced differ between crops due to different levels of irrigation water that are required for production. As Figure 24 shows, in the wet year reference scenario, sustainable crop production of vegetables is highest at 3,275,467 t/year when the water price is AU$ 70/ML. Production of grapes, vegetables, and fruits increase slightly until a water price of AU$ 70/ML since production is determined by the reducing algorithm and sustainable production is not equal to optimal production under the condition of profit maximisation (see Subsection 5.1.6 – reducing algorithm).

Vegetables have the best ratio between the percentage of water applied and the percentage of GVIAP (see Appendix 7.6) and production is more water price inelastic than for cotton or rice. Until a water price of AU$ 150/ML, vegetables have the highest output and lowest water consumption compared to the other crops. Besides vegetables, the fruit industry also has a high water efficiency and high GVIAP.

Vegetables are the only crop that is produced until a water price of AU$ 840/ML. Fruit production continues until a water price of AU$ 680/ML, and grape production until a water price of AU$ 420/ML. In contrast to these water high value crops, rice production (which has the second worst ratio between the percentage of water applied and the percentage of GVIAP) stops at a water price of AU$ 170/ML and cotton (with the worst ratio between the percentage of water applied and the percentage of GVIAP) at AU$ 210/ML.

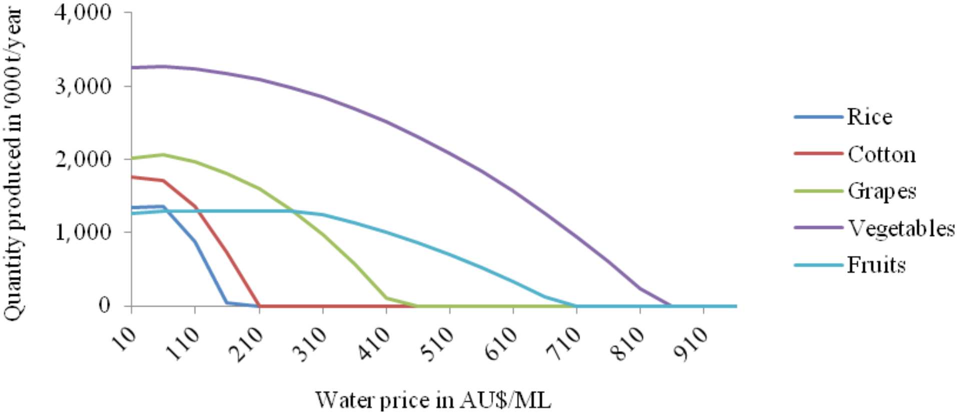

Figure 24: Crop production – wet year – reference scenario

The maximum production of fruits is limited to 1,300,000 t/year in the WatIM-Model runs (as observed in history – see Subsection 5.1.4). Without the limitation of the production, the maximum vegetable production would be 3,297,866 t/year when the water price is AU$ 10/ML. Since production is limited until a water price of AU$ 270/ML, water consumption of the fruit industry is more or less constant at a level of 689 GL/year. For higher water prices, water consumption decreases due to shrinking production.

Dry year – Reference scenario

In the dry year reference scenario, the water applied for production has to be reduced by the reducing algorithm until a water price of AU$ 340/ML. Hence, the water price must be AU$ 350/ML or higher to reflect water availability, which in this scenario, is 1,223 GL/year. Lower water prices are unsustainable[84] and would result in over-consumption of water. As Figure 25 shows, vegetable production is highest, followed by grapes and fruits. Due to fewer water resources, production of these crops is lower (grapes -40 %, vegetables -17 %, fruits -31 %) than in the wet year reference scenario, at a water price level of AU$ 10/ML.

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[84] Regarding water extraction levels.

In the dry year reference scenario, there is no rice and no cotton production at any water price level. Vegetables have the highest production rate at 2,681,836 t/year when the water price is AU$ 10/ML. Grape production experiences a continual decline and ceases at a water price of AU$ 420/ML. Vegetable and fruit production are more water price inelastic than grape production since production of these crops only starts to fall significantly at a water price level of AU$ 350/ML. Fruit production ceases at a water price of AU$ 690/ML and vegetable production stops at a level of AU$ 850/ML.

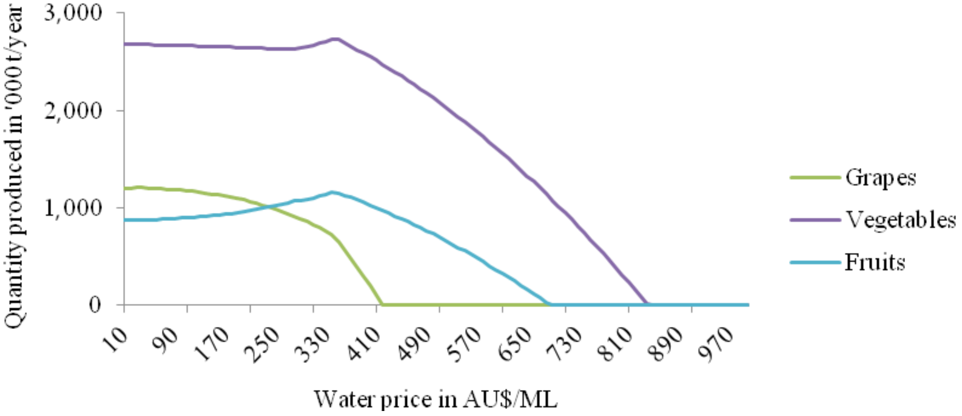

Figure 25: Crop production – dry year – reference scenario

At a water price of AU$ 310/ML and higher, grape production experiences a more rapid decrease. For this reason, more water is available for the other two markets since less water needs to be reduced by the reducing algorithm as described in Subsection 5.1.6. Consequently the crop production of fruits and vegetables increase until a water price of AU$ 340/ML.

This re-allocation is also reflected in the water consumption of the crops. With decreasing water consumption of the grape industry, the water use of fruits rises and water consumption of vegetables slightly increases as well.

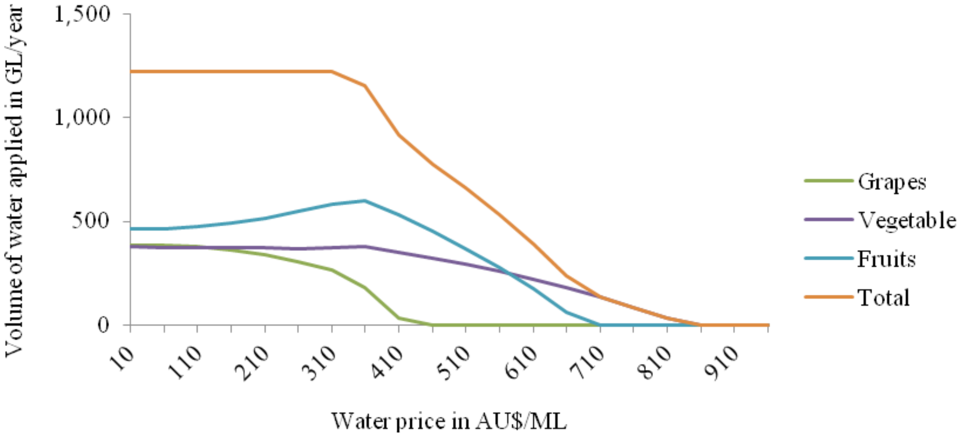

Figure 26: Water consumption – dry year – reference scenario

5.1.7.2 Water Sharing Plan – Scenario 1

The non-pricing, non-monetary WMP of water sharing planning quantitatively reduces the maximum water extraction levels (caps) as outlined in Subsection 4.1. By introducing the Basin plan, additional water is given to the environment. In maximum, approximately 4,000 GL less water could be available for irrigation issues. The main goal of this WMP is to prevent over-consumption of water resources that occurred in the MDB in the past.

The reduction of available irrigation water will be severe for the five crop markets of rice, cotton, grapes, vegetables, and fruits in the MDB. On the basis of the above mentioned maximum reduction, the WatIM-Model's water sharing plan scenario 1 estimates water availability to be 2,000 GL less than in the reference scenario for these five markets. Hence, the analysis of the impacts of the water sharing plan strategy on the five crop markets is based on a water availability of 0 ML/year for the dry year scenario and 4,024 GL/year for the wet year scenario.

Wet year – water sharing plan scenario 1

In the wet year scenario 1, water applied needs to be reduced by the reducing algorithm until a water price of AU$ 130/ML is reached to reflect water availability, which is 4,024 GL/year. In the reference scenario, the minimum water price must be AU$ 70/ML to reflect sustainable water extraction. Hence, the water price under sustainable conditions would be twice as high under the water plan management tool.

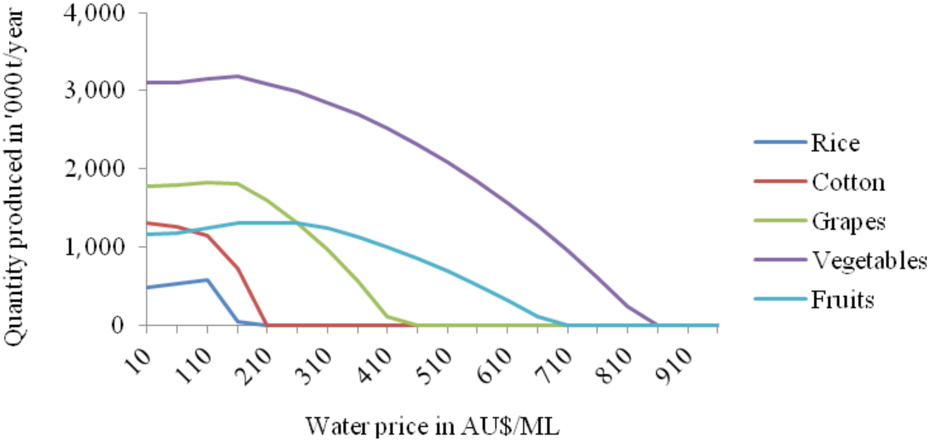

Figure 27: Crop production – wet year – water sharing plan scenario 1

As shown in Figure 27, rice production stops at a water price of AU$ 170/ML and cotton is no longer produced when the water price exceeds AU$ 210/ML. Even at lower water prices, the water low value crops rice and cotton are less cultivated in the wet year scenario 1 than in the wet year reference scenario. For instance, at a water price of AU$ 10/ML, rice production is approximately 850,000 t/year less than in the basic wet year scenario, and cotton production is approximately 450,000 t/year less.

In contrast, productions of other crops do not differ substantially from the reference scenario. Vegetables are produced in the wet year scenario 1 until the water price reaches AU$ 840/ML, fruits until a water price of AU$ 680/ML, and grapes are cultivated when the water price is lower than AU$ 430/ML.

When comparing crop production under the Basin Plan with the reference scenario, rice production decreases by an average[85] of 50 %, and cotton production by an average of 19 % after applying the Basin Plan. Grape production is less af-

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[85] The average is determined by aggregating quantities produced at each observed price level and calculating the percentage change by comparing the sum of the reference scenario outputs and the sum of the WMP scenario outputs.

fected since its production is on average 5 % lower than in the reference scenario. Fruit production decreases by an average of 2 %, while vegetable production decreases the least with an average of 1 % in the water sharing plan scenario 1 when compared with the reference scenario (see Figure 49). Consequently, the introduction of the water sharing plan instrument that reduces water availability for consumption by 2,000 GL has a major impact on water low value crops, especially rice, and less of an impact on water high value crops in wet years.

As indicated in Figure 28, cotton industry is the highest water consumer with 1,684,059 ML/year (at a water price of AU$ 10/ML), however as water prices increase, water consumption decreases rapidly. Therefore, water is re-distributed by the reducing algorithm for the benefit of the other crops. Although quantity of produced rice is much less in scenario 1 than in the reference scenario, rice benefits from this re-allocation and increases until the water price is AU$ 130/ML which can be seen in Figure 28. If the water price is higher than AU$ 130/ML, water consumption of the rice industry rapidly decreases.

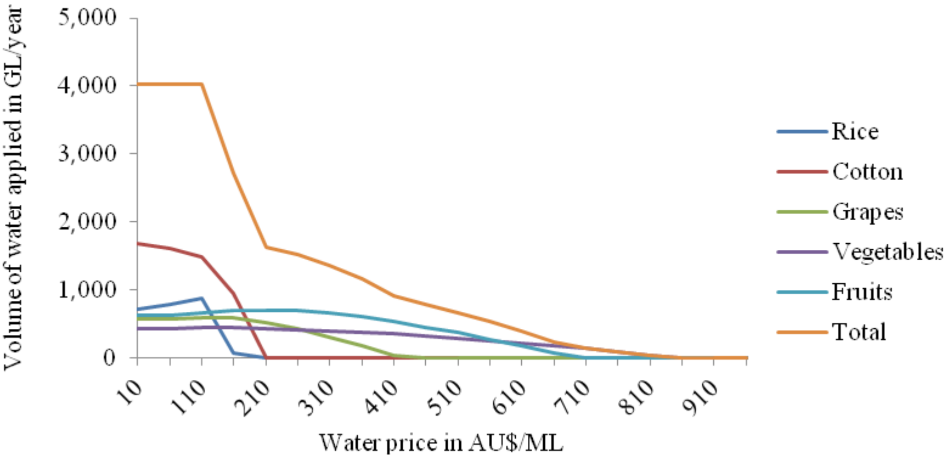

Figure 28: Water consumption – wet year – water sharing plan scenario 1

In comparison to the reference scenario, at a water price of AU$ 10/ML under the water sharing plan condition, water consumption of rice is 1,271,446 ML/year less and for cotton it is 577,128 ML/year less. This mirrors the poor ratio of the percentage of water applied to the percentage of GVIAP for rice, which is worst at 4.18[86] (see Appendix 7.6) in wet years, followed by cotton at 1.87.

It can be concluded that the WMP of water sharing plans has a bigger impact on water low value crops than on water high value crops. Therefore, regions of the MDB where mainly rice and cotton are cultivated are affected the most, even under wet year conditions. The impacts of the water sharing plan policy are even more severe in dry years as described below.

Dry year – water sharing plan scenario 1

In the dry year scenario 1, available water for consumption was reduced by the water sharing plan policy to a volume of 0 ML/year. This is due to the reduction of consumption water by 2,000 GL from the initial value of 1,223 GL/year in the basic dry year scenario.

Hence, crop irrigation is not possible if applied WMPs reduce the amount of available water to zero.

5.1.7.2.1 Comparison to Other Results

In the WatIM-Model's dry year water sharing plan scenario 1, no water is available for irrigation issues for the five observed crop markets due to the large reduction of available water. Therefore, only results of the wet year scenario are compared with other results.

Adamson et al. from the University of Queensland – School of Economics, Australia developed the state contingent MDB model[87] that can be used to analyse regional impacts of the Basin Plan.

This model has three states of nature: normal, drought, and wet. "Normal is assumed to occur 50 % of the time, the drought 20 % and the wet 30 %" (Adamson, 2013). Only the wet state of nature is relevant for the comparison since irrigated crop production in the WatIM-Model is only possible in the wet year scenario.

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[86] The ratio of the percentage of water applied to the percentage of GVIAP for grapes is 0.9; for vegetables 0.36; and for fruits 0.63 in wet year scenarios.

[87] The state contingent MDB "model is an optimisation model [… that] maximises economic return subject to set conditions (river flow, water quality)." (Adamson, 2013).

There is a big difference when comparing the assumed total water consumption of the WatIM-Models wet year water sharing plan scenario 1 with the state contingent MDB model. While in the WatIM-Model the initial water consumption for a wet year is 6,024 GL/year and 4,024 GL/year when applying the WMP water sharing plan, in the model of Adamson et al., the initial water consumption is 13,345 GL/year and 11,732 GL/year under the water sharing plan. The reason for the higher volumes in the state contingent MDB model is that this is the total volume of water usage of all crops in the MDB (not only for the five crop markets as implemented in the WatIM-Model – see Subsection 5.1.6).

For the comparison, the state contingent MDB model sets "all commodities apart from rice, cotton, grapes, veg, fruits (stone fruit, pome fruit) to yield = 0 (so they don't appear in the runs)". (Adamson, 2013). Consequently, the total Basin's water consumption equals water consumption of the five crop markets whereas in the WatIM-Model, water consumption is only considered for the five crop markets.

Even though the initial values of total water availability and therefore water consumption of the five crop markets differ between the models, changes in water consumption at increasing water prices and the impacts of the introduction of SDLs can be compared.

Runs were made with the state contingent MDB model for the five observed crop markets (rice, cotton, grapes, fruits, and vegetables). Adamson et al. provided the resulting data on CDLs, which corresponds to the wet year reference scenario and on SDLs when applying the WMP (Basin plan).

The following figures show results from the state contingent MDB model. Figure 29 illustrates data from the SDL runs in wet state conditions. Figure 30 shows the differences between water use under CDLs and SDLs.

In all diagrams, water price increments are 25 until a water price of AU$ 350/ML, 50 until a water price of AU$ 500/ML, and 100 until a water price of AU$ 1,000/ML. For the rice industry, the "reduction in allowable offtake only lasts […] until [AU]$125 [which means that water consumption for rice is not possible when higher than that]. After a water price of AU$ 150/ML, increasing price has same impact as reducing water for irrigation for everything apart from grapes. The difference in the grapes will hold." (Adamson, 2013).

Additionally, no water consumption of vegetables appears since "vegetables do appear implicitly in the rice production systems. The rice production system is 1/3 area rice, 2/3 area wheat (based on current rules in the area) and then a veg[etable] crop is sown in after in the normal and wet states, in the drought state there is not enough soil moisture." (Adamson, 2013).

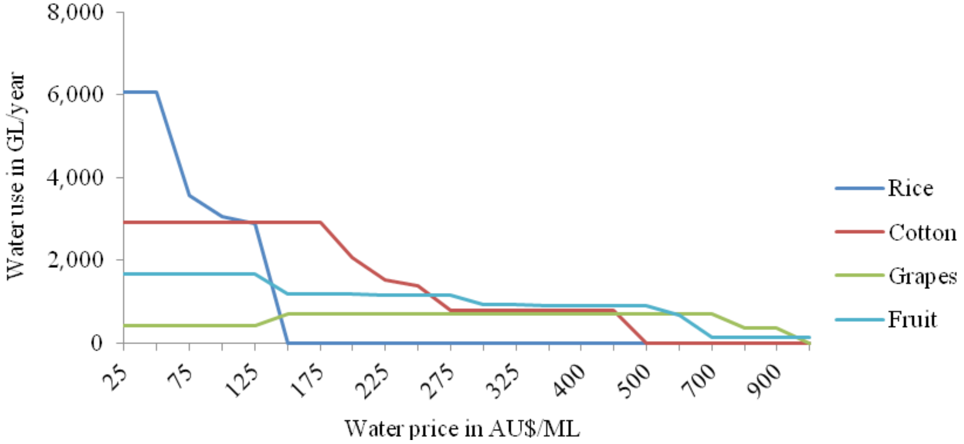

Figure 29: SDL data from the state contingent MDB model – wet year (own illustration, data provided by David Adamson from the University of Queensland – School of Economics).

Apart from the differences of total water consumption between the models, rice and cotton are the largest water consumers in both models when water prices are low (for the WatIM-Model scenario see Figure 28). In both models, water consumption of those water low value crops decreases the most while fruits and grapes (vegetables are included in rice in the state contingent MDB model and cannot be separated for this comparison) decrease more slowly. In the WatIM-Model, fruits' water consumption stops at a water price level of AU$ 680/ML and is nearly zero when the water price exceeds AU$ 700/ML in the state contingent MDB model. Grapes' water consumption stops when the water price goes beyond AU$ 420/ML (WatIM-Model) and AU$ 900/ML (state contingent MDB model) respectively. Water consumption of rice is zero when the water price exceeds AU$ 160/ML (WatIM-Model) and AU$ 125/ML (state contingent MDB model). Cotton does not consume water when the water price exceeds

AU$ 200/ML in the WatIM-Model. In the state contingent MDB model, cotton experiences a sharp decrease at a water price above AU$ 275/ML and ceases to consume water at AU$ 450/ML. Consequently, both models estimate water consumption of the observed crop types to cease at more or less the same water prices.

Figure 30 illustrates the change of water consumption in the state contingent MDB model when applying WMPs of water sharing plans.

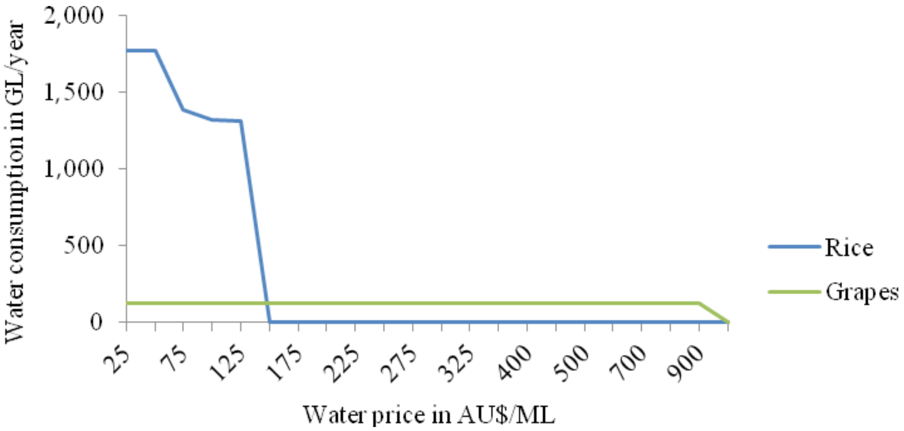

Figure 30: State contingent MDB model – differences of water consumption between CDL and SDL water consumption (own illustration – data provided by David Adamson from the University of Queensland – School of Economics).

While SDLs have no effect on water use for fruits, water consumption for grapes is constant at any water price level at 236 GL/year.

Figure 31 shows that similar results can be obtained from the WatIM-Model where the difference between water consumption for fruits and grapes are nearly constant at a low level.

Rice is the only crop which reacts in both models on the implementation of SDLs with a significant decrease of water use. At a water price level of AU$ 25/ML, rice (including vegetables) consumes 1,776 GL less water in the state contingent MDB model. This effect is nearly the same in the wet year scenarios of the

WatIM-Model as illustrated in Figure 31. When comparing results of the reference scenario and the water sharing plan scenario 1, a maximum decrease of water consumption of rice of 1,271 GL/year (at a water price of AU$ 10/ML) can be recorded.

In both models, rice is mostly affected by the introduction of the water sharing plan policy and the resulting reduction of available irrigation water.

Despite many similarities between the results of both models, the difference in water consumption of cotton is not the same. While SDLs show no effect on cotton production in the model of Adamson et al., in the WatIM-Model a significant decrease in water consumption and therefore cotton production is noticeable.

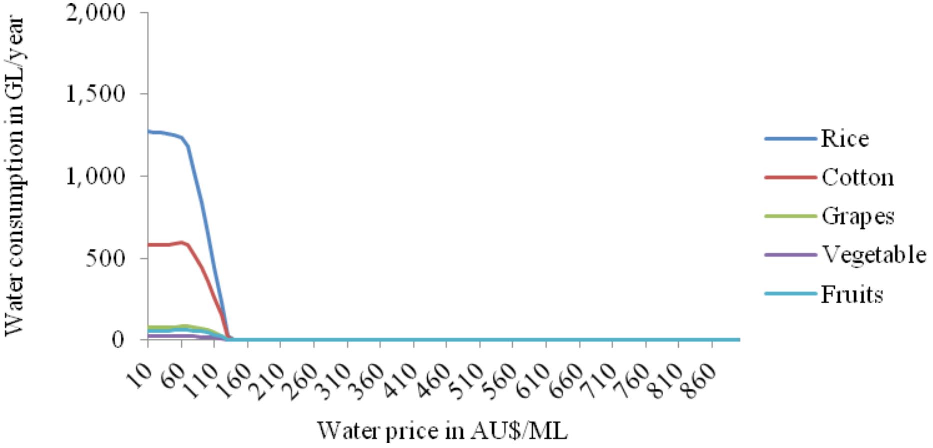

Figure 31: WatIM-Model – differences of water consumption between reference scenario and water sharing plan scenario 1 – wet year

As the comparison of both model outputs also shows, effects on water consumption are highest when the water price is lowest. With an increasing water price, the differences between CDL/SDL or reference scenario/water sharing plan scenario 1 gets smaller. In the WatIM-Model differences are zero for all crops when the water price reaches AU$ 140/ML. Similarly, in the state contingent MDB model, the difference of water consumption of rice is zero when the water price exceeds AU$ 125/ML.

In conclusion, the overall impact of the implementation of the water sharing plan policy (which defines new SDLs) on agricultural production of the five observed crop markets are similar in both models.

5.1.7.2.2 Conclusion of Scenario 1

Over-allocation and therefore over-consumption of water was one result of governmental failure in the MDB since a farmers supporting policy allowed irrigators to extract too much water particularly during droughts. This is associated with a missing cross-border coordination of water right providing of the state governments.

By introducing the Basin Plan, which is accompanied by the implementation of SDLs, water availability for irrigation issues is mandatorily decreased on a Basin-wide scale. The Basin Plan is supposed to reduce water extraction by 3,000 to 4,000 GL/year on the Basin scale for the benefit of the environment. Since water consumption for the five observed crop markets *m* is about half of total annual water diversion of all users in the MDB, available water was reduced by 2,000 GL in comparison to the reference scenario for the water sharing plan scenario 1 analysis in the WatIM-Model.

By applying such a non-pricing, non-monetary institutional arrangement, previous over-consumption of water is meant to be corrected by tightening the cap on extractable water. The targets of environmental protection and irrigators' support are in conflict and therefore not pursuable at the same time. Previously, state policies concentrated on irrigators' support, which will change in the future with the Basin Plan. Environmental protection increasingly receives more attention and represents the primary goal of the Basin Plan. By reducing water availability for irrigation issues and leaving this water for the environment, this objective might be fulfilled in the future. This will result in severe impacts on the agricultural industry in the Basin and causes high transaction costs.

For the scenario analysis, it is assumed that decreases of irrigation water availability apply to all crop types simultaneously. In reality, some regions will be more, some less, while others will not be affected at all by the future SDLs. Therefore this instrument does not provide a general incentive for water saving behaviour and is not generally increasing water use efficiencies.

Generally, water sharing plans are important in order to achieve sustainable extraction levels. For the determination of extractable volume of water, it is indispensable to take into account total water availability in resource systems. It is necessary to determine the volume of available water within each single consumption-pool as precisely as possible. It must be defined how much water must be left within this pool for the environment to keep sustainable water levels. Additionally, water losses due to evaporation or transportation system losses (e. g. pipe burst) must be taken into account. No more than the resulting volume should be announced by the government as available water for consumption. During times of drought, this volume might actually be zero with the consequence that no water would be available for irrigation. Consequently, water sharing plans, which are the result of water planning, play a key role when defining water supply levels.

In addition, to the Basin Plan implementation, the MDBA takes over responsibility of the water management for the whole Basin, which is important since rivers cross state borders as well. The lack of coordination of water planning between Basin states is removed with this step. Additionally, the MDBA controls and plans water consumption.

In consideration of the WatIM-Model's assumptions and constraints (see Subsections 5.1.1 to 5.1.6), it can be concluded that the WMP water sharing plan has major impacts on irrigated crop production in the MDB. Even in the wet year water sharing plan scenario 1, where 4,024 GL/year irrigation water is available, effects on irrigation industry are noticeable. As a result of the wet year water sharing plan simulation with the WatIM-Model, the water price has to be at least AU$ 140/ML to be considered sustainable, which is twice as high as in the reference scenario. In comparison to the reference scenario, the rice and cotton industry experienced significant reductions in crop production since their water productivity is not as good as the others.

In the dry year water sharing plan scenario 1, no water is available for irrigation. This means even perennial plants would not have a chance of survival during drought periods when no irrigation water is available and all other resources (e. g. on-farm storage) are exhausted. Hence, water sharing plans would have a severe impact on the irrigation industry if the reduced amount of water is equally applied in dry and wet periods (concept is shown in Figure 9). The consequence is that no irrigation water dependent perennials could be cultivated anymore. Agricultural land would lay fallow or used only for rain-fed farming.

Hence, over-consumption and therefore environmental damages in the Basin may be prevented in future by implementing the Basin Plan. Essential for a successful implementation of SDLs is the selection of the "right" approach (see Figure 10). Economic losses due to a decrease of irrigated production in the Basin and the occurrence of high transaction costs may be consequences of implementing such a non-pricing, non-monetary instrument.

5.1.7.3 RtB Program – Scenario 2

The non-pricing, monetary RtB program is aimed at reducing the previously observed over-consumption of irrigation water and to restore the balance in the MDB (ABARE-BRS, 2010, p. 12) in the long term. By governmental interaction on the water market, water access entitlements are bought from willing sellers and the availability of water on the market is reduced. As a result, water can be given back to the environment.

By 2010–11, the accumulated volume of water access entitlements purchased by the Australian government in the RtB program was about 1,000 GL (see Figure 11). Based on this data, it is assumed that available irrigation water is decreased by 1,000 GL for scenario 2 due to the RtB program. Consequently, available water for the five crop markets in the MDB is calculated to be 223 GL/year for the dry year scenario 2, and 5,024 GL/year for the wet year scenario 2.

Wet year – RtB program scenario 2

In the wet year scenario 2, a minimum water price of AU$ 110/ML would reflect water availability of 5,024 GL/year. Lower water prices are unsustainable because they would lead to over-consumption without applying the reducing algorithm[88]. Vegetable production is highest with 3,241,867 t/year followed by grapes with 1,974,800 t/year at a water price of AU$ 110/ML.

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[88] Under the condition that the announced limit of extractable water (which can be also called the defined maximum of available water) is sustainable.

If the water price is higher than AU$ 160/ML, rice will no longer be produced. Cotton production would stop at a water price of AU$ 210/ML, grape production at a water price level of AU$ 430/ML and fruit production at AU$ 690/ML.

The higher the water productivity (ratio of percentage of water applied to percentage of GVIAP) of a crop, the longer a crop can be produced with increasing water prices and the less water price elastic is the water demand of that kind of crop. The vegetable sector has the best water productivity. Therefore, this high value crop is cultivated until a water price of AU$ 850/ML as illustrated in Figure 32.

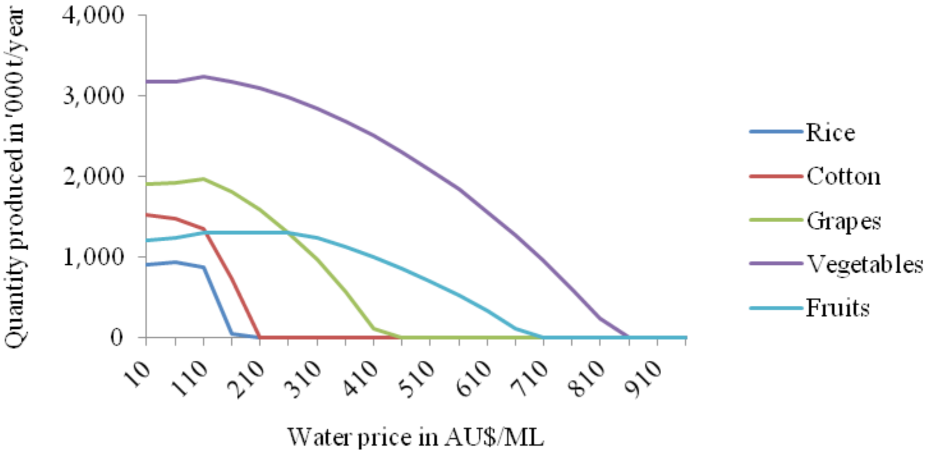

Figure 32: Crop production – wet year – RtB program scenario 2

Since vegetables have the highest crop output and the lowest water consumption until a water price of AU$ 140/ML is reached (see Figure 33), vegetable production benefits from the re-allocation when applying the reducing algorithm. Likewise, grape and fruit production increases slightly with decreasing cotton and rice production. Accordingly, water is re-allocated at the expense of water low value crops and in favour of water high value crops by the reducing algorithm.

Figure 33 illustrates how rapidly water consumption of cotton and rice industry decreases with a water price higher than AU$ 120/ML. Water low value crops are very water price elastic in contrast to water high value crops. Water consumption of vegetables are more or less constant until a water price of AU$ 410/ML, then it decreases slightly with rising water prices until water consumption is zero at a water price of AU$ 850/ML.

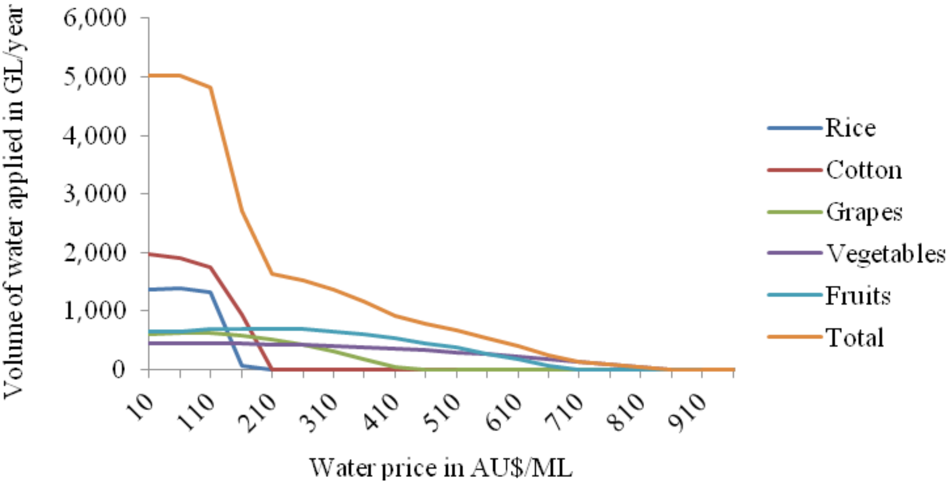

Figure 33: Water consumption – wet year – RtB program scenario 2

In comparison to the reference scenario, total water consumption is 1,000 GL/year less. This has an effect on the water consumption of all crops. Especially clear are influences on cotton industry with approximately 300 GL/year and on the rice industry with approximately 650 GL/year less water consumed at a water price level of AU$ 10/ML. Effects on the water high value crops grapes, vegetables and fruits are comparatively small.

Hence, under wet year conditions, the WMP of buying back water access entitlements, limits the crop industry mainly, which is highly water dependent and less water efficient. This correlation becomes even more evident in the dry year scenario 2.

Dry year – RtB program scenario 2

The dry year scenario 2 assumes the total water availability for the five crop markets rice, cotton, grapes, vegetables, and fruits to be 223 GL/year in the MDB. With such a small volume of water available for irrigation, not all crops can be cultivated. Rice, cotton, and grapes are not produced in the dry year scenario 2. The water high value crops, fruits, and vegetables are cultivated as illustrated in Figure 34.

However, fruit production stops at a water price level of AU$ 690/ML and vegetable production at a level of AU$ 850/ML, which are the same as in the reference dry year scenario. Vegetable production is highest with 1,467,654 t/year at a water price of AU$ 10/ML, whereas fruit production increases with the rising water price until a maximum of 142,158 t/year at a water price of AU$ 590/ML is achieved. This trend can be explained by the reducing algorithm that must be applied until a water price of AU$ 660/ML. If the water price is lower than AU$ 670/ML, water consumption would be unsustainable without the reducing algorithm since it would exceed available water resources for irrigation.

Originating from the optimal production level under profit maximisation, vegetable production decreases with increasing water prices. Therefore, more water can be used for fruit production until it is no longer profitable (due to high production costs caused by higher water prices). At this point, fruit production decreases. At the same time, vegetable production increases until the water price reaches AU$ 670/ML. This is because more irrigation water is available for vegetable cultivation. The drop in vegetable production is relatively small until a water price of AU$ 600/ML in comparison to the fall that can be observed from a water price of AU$ 670/ML and upwards. Therefore, water price elasticity of the vegetable industry is higher with higher water prices.

The same trade-off behaviour between vegetables and fruits can be monitored for water consumption in Figure 35. The difference between the curves is not as great, as in the case of crop production, because water consumption used for crop cultivation is much higher for fruits than it is for vegetables. For example, to produce 83,467 t of vegetables, 11,685 ML must be used (water price: AU$ 830/ML). In contrast, 44,798 ML must be applied (water price: AU$ 360/ML) to produce 84,525 t of fruit. Thus, water consumption for producing one tonne of fruit is nearly four times as high as for one tonne of vegetables.

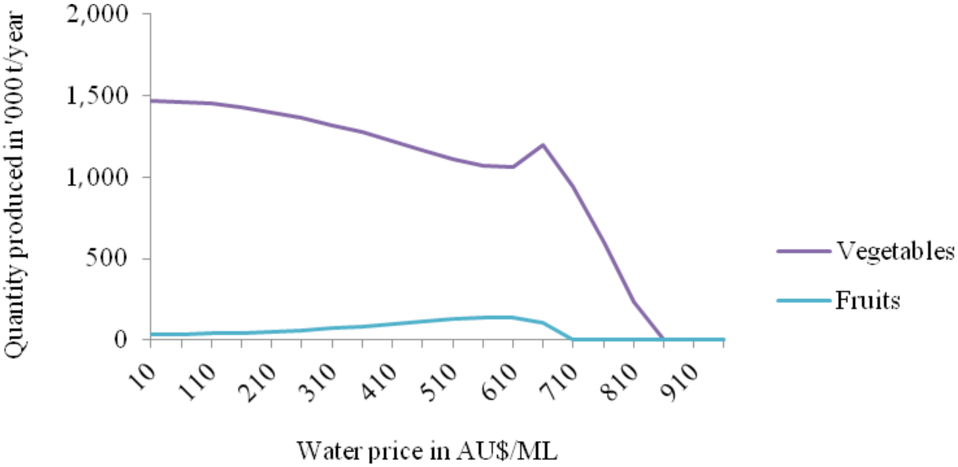

Figure 34: Crop production – dry year – RtB program scenario 2

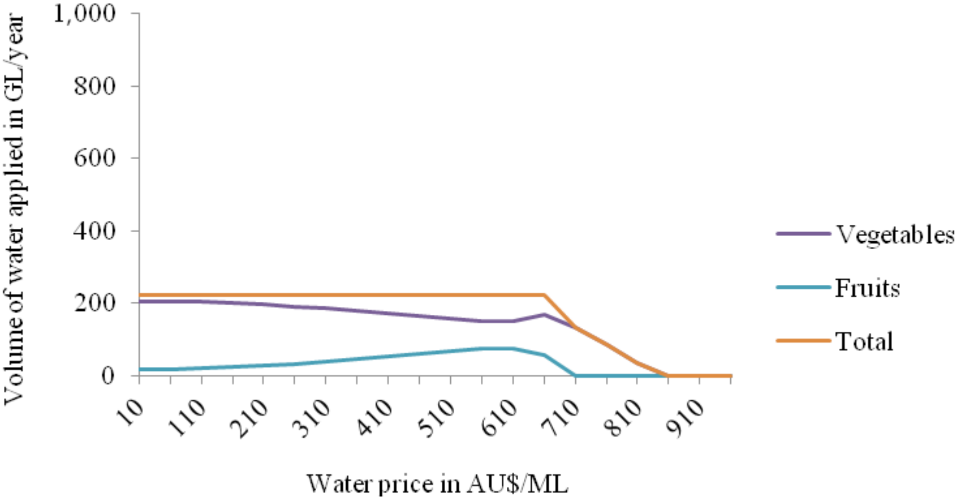

Figure 35: Water consumption – dry year – RtB program scenario 2

Total water consumption is limited to 223 GL/year by the reducing algorithm until a water price of AU$ 660/ML to prevent over-consumption of water. With the cessation of fruit production, water consumption of vegetables is identical with total water consumption starting at a price of AU$ 690/ML.

5.1.7.3.1 Comparison to Other Results

Dixon et al. (2012) from the Monash University, Australia used the TERM-H2O model to simulate effects of the RtB program on the agricultural sector in the southern MDB (SMDB) (Dixon et al., 2012, p. 104). They assume that the Australian government buys 1,500 GL of water access entitlements from irrigators over the period from 2009 to 2016 in the SMDB. They analysed impacts of the RtB program for the year 2018, which is assumed to be a year of normal rainfall, and therefore 70 to 90 % of the water access entitlements are allocated. This results in a reduction of available water by 1,050 to 1,350 GL/year in the SMDB. In addition to lower water availability, Dixon et al. (2012) also assume a water price increase from approximately AU$ 20/ML in 2006 to AU$ 120/ML in 2018. Findings derived from the TERM-H2O model are "percentage effects of the RtB scheme on farm industry outputs in regions of SMDB in 2018." (Dixon et al., 2012, p. 104). They predict that the production of rice decreases by 20.6 %, irrigated cotton declines by 12.5 %, grapes by 4.2 %, and irrigated fruits by 0.5 %. In addition they found that the production of less water dependent crops increases (cotton-dry by 19.5 %, fruit-dry by 8.3 %, and vegetables by 5.0 %). (ibid., 105).

To be able to compare these results with data derived from the WatIM-Model, percentage changes were determined. The calculation is based on crop production in the wet year reference scenario at a price of AU$ 20/ML and production in the RtB program scenario 2 at a water price of AU$ 120/ML.

The findings of the WatIM-Model show a decrease of rice production by 44.9 % and a decrease in cotton production of 22.8 %. Grape production with a decrease of 3.8 % and vegetable production with a decrease of 0.6 % were far less affected by the RtB program while fruit production experienced a slight increase of 2.6 %.

Even though the TERM-H2O model and the WatIM-Model analysed the various impacts of the RtB program and the resulting percentage changes of crop production base on the same water prices, there were several basic conditions and assumptions that differed between each model. These were for instance, the area of observation (MDB versus SMDB, where different types of crops are cultivated), the total volume of available water for irrigation, and the distinction of dry and irrigated cotton and fruits in the model of Dixon et al., which is not done in the WatIM-Model[89].

These fundamental differences between both models might account for varying percentage changes in the predicted crop production.

Comparing the results of both models, it is evident the RtB program has a very similar impact on crop production. In both models, the rice market has the greatest production losses with the most significant decrease seen using the WatIM-Model.

The same results can be observed for the production of cotton, which like rice is a low value crop. Cotton production decreases more significantly in the WatIM-Model.

The results of both models show, that high value crops such as grapes, vegetables and fruits are far less affected by the RtB program. When comparing percentage production changes of these three high value crops, maximal percentage changes can be observed for grapes with a decrease of 3.8 % in the WatIM-Model and for vegetables with an increase of 5.0 % in the TERM-H2O model.

In conclusion, both models record major decreases of water low value crop production and only low changes of water high value crop production due to the RtB program.

5.1.7.3.2 Conclusion of Scenario 2

The RtB program is a non-pricing, monetary demand regulating WMP with the aim to quantitatively reduce available water rights on the water market in order to prevent the over-consumption of water. Since the Australian government is buying back water from the water market, a reduction of 1,000 GL of available irrigation water is assumed for the RtB program scenario 2. Compared with the higher water availability in the reference scenario of the WatIM-Model, outputs show significant consequences on the five observed crop markets.

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[89] Since more than 80 % of the cultivated area of cotton, rice, grapes and vegetables is irrigated (own calculation on the basis of data from Australian Bureau of Statistics, 2010f, Table 1), the author decided not to take the distinction of dry and irrigated crops into consideration.

Without applying the reducing algorithm, water would be over-consumed until a water price of AU$ 660/ML in dry years and AU$ 110/ML in wet years. In contrast, in the reference scenario, the minimum water price must be AU$ 350/ML in dry years and AU$ 70/ML in wet years in order to be sustainable. Since less water is available under the RtB program, higher water prices are necessary to deal with the higher scarcity of irrigation water and to prevent unsustainable over-consumption of the irrigation water.

The effects on crop production caused by the introduction of the RtB program are diverse. In the wet year scenario, water high value crops (grapes, vegetables and fruits) are not affected by the reduction of available water. However, the reactions of the water low value crops are more significant. In comparison to the wet year – reference scenario, where no WMP was applied, crop production of rice decreased by an average of 23 % while cotton decreased by an average of 8 % (see Figure 49)[90]. The influence of the RtB program is more profound in dry years. Rice, cotton, and grapes are not produced in the dry year scenario at all. In comparison, a zero production at any water price only applied to rice and cotton in the dry year – reference scenario. Grape production is therefore highly effected by this policy during dry years. Since grapes are perennials, and cannot be irrigated during dry years under the RtB program scenario, grape vines would die with the consequence that industrial grape cultivation would be not possible anymore in the MDB.

It can be concluded that the RtB program could be a proper instrument to counteract the observed over-consumption in the MDB.

The reduction of available water access entitlements may result in a reduction of water consumption, which is beneficial for the environment but only when the state governments' announcements of water allocations do not increase. Water allocations rather than water access entitlements determine the extractable volume of water. Consequently, the success of the RtB program, which is a Commonwealth program, is highly dependent on Basin state governments' decisions concerning water extraction levels and water planning policies.

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[90] The average is determined by aggregating quantities produced at each observed price level and calculating the percentage change by comparing the sum of the reference scenario outputs and the sum of the WMP scenario outputs.

5.1.8 Scenario Analysis – Pricing Strategies

While the various impacts of water availability reducing strategies on irrigated crop production were examined in the previous chapter, in this section two water pricing strategies are observed. The effects of a full cost recovery pricing approach are analysed in Subsection 5.1.8.1, while the influences of the environment compensation irrigation tax are evaluated in Subsection 5.1.8.2.

5.1.8.1 Subsidy Removing – Scenario 3

As illustrated in Subsection 3.3.3, water prices charged by service providers in the MDB are not the result of market forces but are predefined for longer periods of time by independent institutions. This pricing mechanism led to unsustainable water consumption in the past. Therefore, it is meaningful to either allow the water market to establish an equilibrium water price or to apply appropriate water pricing policies.

The first analysed water pricing strategy is designed to completely remove all subsidies and grants from governments that previously supported water suppliers. The goal of this cost-oriented (see Subsection 4.3), mandatory pricing strategy is to reduce over-consumption of water by achieving rural water price levels, which are capable of completely covering the costs of the water service providers.

As previously mentioned, by using this WMP, irrigating farmers will be primarily affected since they are the largest water consumers of rural water. By applying the cost-oriented approach, the water price must be significantly increased, since subsidies covered a large share of the suppliers' costs (C_{ws}) in the past.

Using New South Wales as an example, 31.4 % of the total suppliers' costs were covered by subsidies and governmental grants in 2009–10 (IPART, 2010, p. 7). In this case, the total water price for irrigators would need to be increased by 45.77 % for full-cost recovery. Since New South Wales covers the largest area of the MDB with 56 %, the example of this state is seen, in this thesis, as representative for the other states. It is also assumed that the ratio of costs to the volume of water deliveries of the New South Wales water supplier State Water are representatitve for all water service providers in the Basin.

For the case of New South Wales, in Subsection 3.3.3.2 it is explained that total expenditures of water providers do not depend on the volume of water deliveries or fluctuations in water availability. Therefore, for the subsidy removing scenario 3, total suppliers' costs are kept constant at C_{ws} = AU$ 70,049,000/year, which is an average calculated following data from ABS and State Water (see Appendix 7.7).

The water price discussed in the subsidy removing scenario 3 is the total price users would have to pay and includes prices for water access entitlements (not water right trading) and actual water deliveries (see Subsection 3.3.3). Since tariff systems vary across the Basin, a differentiation between single-part and two-part tariffs is not implemented. This may be done in a future research. For the analysis in scenario 3, it is assumed that the water price is volumetric, which means that irrigators pay only for the actual extracted volume of water. A fixed fee (for e. g. water rights which apply also when no water is used) is not charged. Under the above mentioned conditions, the results show an increasing water price when the volume of water delivered by the service provider decreases and a decreasing water price when deliveries increase. The water price corresponds with the cost of delivering one GL of water and can be calculated by dividing the average total annual expenses (C_{ws} = AU$ 70,049,000) by the average volume of delivered water.

As an example, in New South Wales the annual average[91] volume of delivered water is 2,389 GL and the average of the total annual expenses is c_{ws} = AU$ 70,049,000. This results in a water price of AU$ 29,32/ML. This price does not include a profit margin and has to be paid by water users to fully cover the water providers' costs.

This is the calculation method applied in scenario 3 with the goal to receive a full-recovery-water-price.

In the following, the differentiation between wet and dry year scenarios is made using examples that clarify crop production at various levels of water availabil-

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[91] Determined from data provided by State Water's annual reports 2004–05 to 2009–10.

ity under the WMP of subsidy removing and help to analyse the impacts of this strategy.

Wet year

By defining $q_{w\ avail\ diff}$ in the WatIM-Model, it is assumed that on an annual basis at least 2,500 GL of irrigation water is available in a wet year (see Appendix 7.6). Water providers' costs, which must be covered by revenues from water sales to rice, cotton, grape, vegetable, and fruit farmers in the MDB are kept constant at C_{ws} = AU$ 70,049,000/year. The water price must be higher when less water sales are possible due to a lower water availability. Table 8 depicts different wet year cases with five different water availability levels decreasing from 6,024 GL/year in Case A to 2,500 GL/year in Case E.

Referencing the above illustrated calculation, the full-cost-recovery price is in accordance with the available volume of irrigation water, increasing from AU$ 11.63/ML in Case A to AU$ 28.02/ML in Case E.

Consequently, the full-cost-recovery price and the volume of available water for irrigation issues in Table 8 are exogenous variables for the linear WatIM-Model.

Table 8: *Wet year subsidy removing scenario 3 with varying levels of water availability and full-cost-recovery prices*

	Available water in GL/year	**Full-cost-recovery price in AU$/ML**
Case A	6,024[92]	11.63
Case B	5,500	12.74
Case C	4,500	15.57
Case D	3,500	20.01
Case E	2,500	28.02

Figure 36 shows crop production at varying levels of water availabilty and corresponding prices under the WMP of subsidy removing.

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[92] This volume of available water was chosen to enable the comparison of policy impacts with other examined policies in wet years (see Figure 49).

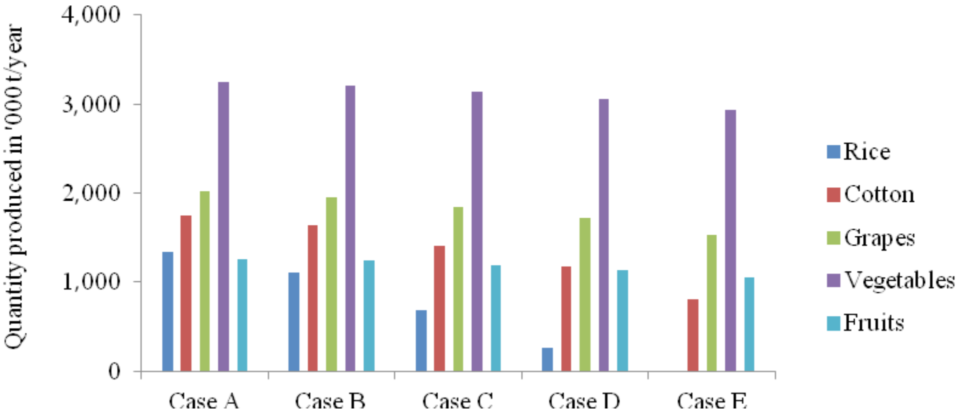

Figure 36: Crop production under the WMP of subsidy removing – wet year

Vegetable production is the highest of all the observed cases with 3,247,664 t/year at a water availability of 6,024 GL/year and a full-cost-recovery price of AU$ 11.63/ML (Case A) and 2,934,464 t/year at a volume of 2,500 GL/year and a full-cost-recovery price of AU$ 28.02/ML (Case E). Vegetable production, with a 10 % decrease is least affected by changing levels of water availability and therefore resulting prices. There is a slightly more negative impact on the production of fruits. It is highest with 1,265,480 t/year (6,024 GL/year water availability – Case A) but decreases by 17 % to 1,051,275 t/year (2,500 GL/year water availability – Case E). Grape production loss is 25 % when comparing crop production of Case A with Case E. The effects of water availability and water price changes on low value crops are very considerable. While the production of cotton decreases by approximately 54 % from Case A to Case E, in Case E there would be no rice production at all.

The results demonstrate that production can vary significantly depending on the type of crop, volume of water availability, and the water price. The higher the water price due to less water availability, the bigger the effects on crop production especially on the water low value crops rice and cotton. Water high value crops are less reactive to changes in water availabilities and the water price.

Observed crop production losses result on the one hand from decreasing water availability levels and on the other hand from increasing water prices resulting from subsidy removing. To show the actual impact of the WMP of subsidy removing, crop production under this WMP has to be compared with crop production without full-cost-recovery prices.

To do so, crop production for all water availability levels observed in Cases A to E were calculated. The water price, which does not cover water supplier's costs was kept constant at AU$ 7.86/ML for all availability levels in the wet year scenario. This is done since prices for water delivieries are predefined by independent institutions and kept constant for longer periods of time in the MDB. The price of AU$ 7.86/ML is an annual average, derived from State Water Corporations data on the volume of water deliveries and revenue from water deliveries in the year 2005–06[93] (State Water Corporation, 2010, p. 8 and 102).

Considering full-cost-recovery water prices as well as the constant water price of AU$ 7.86/ML, a percentage change of crop production for each crop was determined. The maximal production loss is 0.5 % which is negligibly small (see Figure 49).

The reason for this is that in wet years, suppliers' costs can be shared between numerous water sales (assuming that the volume of water availability equals the volume of water sales). Figure 37 (Cases A to E) shows that there is no significant increase in the water price.

The water price is only slightly rising with decreasing water availability from 6,500 GL/year to 2,500 GL/year (which distinguishes dry and wet years in the WatIM-Model).

Hence, the WMP of subsidy removing has very little effect on crop production during wet years when water availability is high.

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[93] For the wet year scenarios in this thesis, the reference year 2000–01 is used. Since no data is available for this year from State Water, the wettest year within the long term drought (from 2001 until 2009) was used to calculate the average annual water price, which was charged in 2004–05. (State Water, Annual report 2004–05).

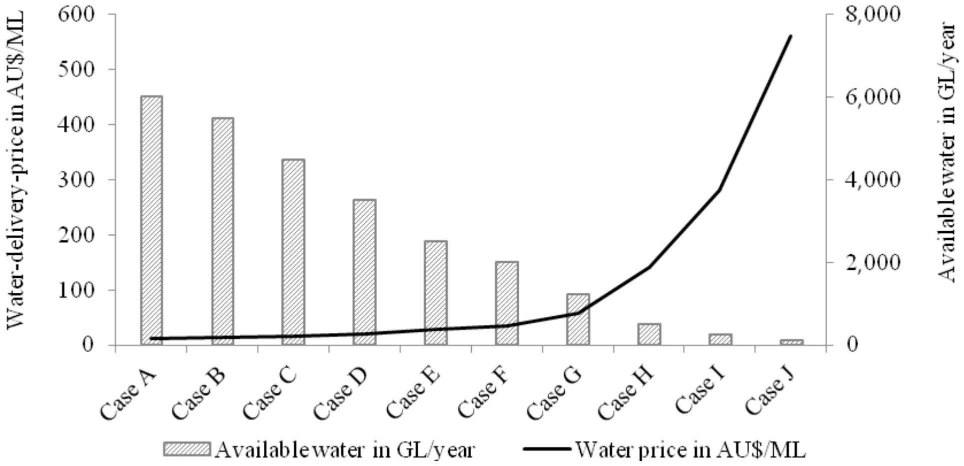

Figure 37: Development of full-cost-recovery price regarding changing water availabilities

Dry year

According to the wet year scenario above, the same approach is applied for the dry year subsidy removing scenario 3.

To illustrate the development of crop production with variable water availabilty in dry years, five cases were chosen for examination. These were 2,000 GL/year, 1,223 GL/year, 500 GL/year, 250 GL/year, and 125 GL/year.

Since water providers' costs are kept constant at AU$ 70,049,000/year, Table 9 shows the associated water prices when costs are fully covered by water sales, which decrease with declining irrigation water availablility. Full-cost-recovery prices derive from the cost recovery calculation, not from predefined proportionalities.

Table 9: Dry year subsidy removing scenario 3 with varying levels of water availability and full-cost-recover prices

	Available water in GL/year	Full-cost-recovery price in AU$/ML
Case F	2,000	35.02
Case G	1,223[94]	57.28
Case H	500	140.10
Case I	250	280.20
Case J	125	560.39

Figure 38 shows crop production under the WMP of subsidy removing at different levels of water availabilty in dry years.

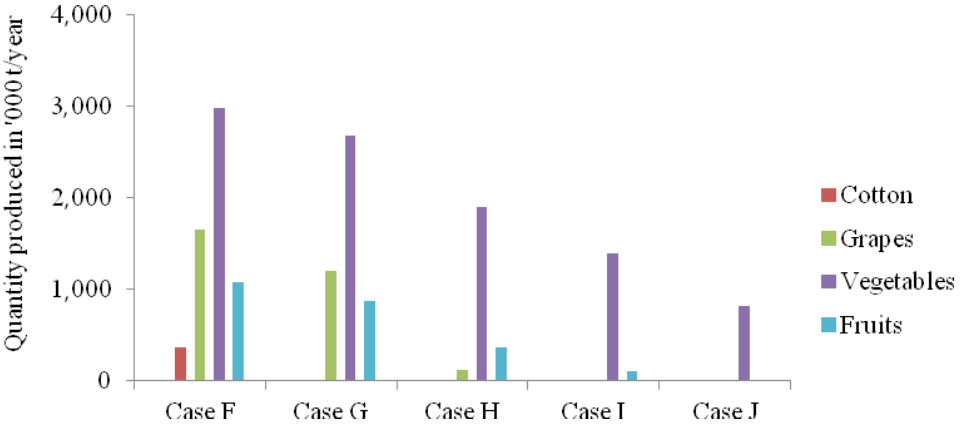

Figure 38: Crop production under the WMP of subsidy removing – dry year

Rice, which is a low value crop, is not produced in any of the five observed dry year cases. Cotton is only produced in Case F at a water availability of 2,000 GL/year and a water price of AU$ 35.02/ML but is not produced in cases where water availability is below 2,000 GL/year.

Grape production is highest with 1,648,566 t/year in Case F but then rapidly decreases to a production of 122,998 t/year in Case H. There is no grape production

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[94] This volume of available water was chosen to enable a comparison of policy impacts with other examined policies in dry years (see Figure 53).

in Cases I and J when water availability decreases even more. Fruits and vegetables are cultivated at all observed levels of water availability but with immense output losses when comparing cases F and J.

While production of fruits decreases by 98 %, vegetable production, which is highest at all levels of water availability decreases by 72 %.

Figure 38 shows that the decrease of grape, vegetable, and fruit production is most significant when water is very scarce and the water price is very high (Cases I and J). Hence, irrigated crop production is highly affected by decreasing water availability levels and rising prices in dry years.

To clarify the actual impact of the WMP of subsidy removing, crop production needs to be compared between full-cost-recovery prices and water prices without this strategy applied.

This is done in the same way as the wet year scenario. Crop production for different dry year water availability levels (which were observed in Cases F to J) was calculated.

The water price, which does not cover water supplier's costs was kept constant at AU$ 27.91/ML for all availability levels in the dry year scenario. This annual average water price was derived from State Water Corporations data on volume of water deliveries and revenue from water deliveries in 2007–08 (State Water Corporation, 2010, p. 9 and 130).

Percentage changes were determined between quantities produced at the constant water price of AU$ 27.91/ML and full-cost-recovery prices.

The subsidy removing policy shows different impacts on crop production. Rice production is not affected by this policy because regardless of the water price, this crop is not produced at any of the observed levels of water availabilities in dry years. Cotton production is only possible at a water availability of 2,000 GL/year and decreases by -0.1 when applying the WMP. Hence, the policy has a negligible impact on water low value crop production in dry years.

When comparing crop production losses of the three water high value crops that result from the introduction of the subsidy removing policy at a water availabiltiy level of 1,223 GL (the level that is equivalent to the dry year reference scenario), then the loss is 0.3 % for grapes, 0.2 % for vegetables, and 0.0 % for fruits (see Figure 53).

As Figure 37 (Cases F to J) shows, the lower the level of water availability, the less sales are possible, resulting in increasing water prices to cover water suppliers' costs. This consequence is very significant when water is very scarce. The higher the water price difference between full-cost-recovery price and the constant water price of AU$ 27.91/ML (without WMP), the bigger the impact of the subsidy removing strategy on irrigated crop production.

5.1.8.1.1 Potentials of a Subsidy Removing Strategy in the Rural Murray-Darling Basin

The idea of differentiating between water prices in dry and wet years, as shown by the application of the WMP of the subsidy removing, is not new. The water service provider SunWater suggested an irrigation price path where the fixed part of the tariffs varies with water availability. SunWater's idea is to reduce the water price in dry years with the goal to diminish costs in years with low water availability and to transfer burden on farmers into water rich years. SunWater recommends the following: when less than 30 % of water allocations can be met, the fixed water price is AU$ 5.11/ML. When more than 70 % of allocations can be met, then the price is AU$ 15.31/ML. (SunWater, 2006, p. 108).

This idea of water pricing is a farmer supportive idea from a social point of view with the intention that farmers face fewer costs when they receive less or no water at all, in times of water scarcity. Nonetheless, this approach of pricing would provide no economic incentives for farmers to save water and it would hinder investments in innovative technology. Additionally, it would be the opposite of price development in free markets when the water price increases with increasing demand and decreasing supply. Therefore, the water price differentiation of SunWater is contrary to allocation efficiency and refuses incentives for efficient water usage.

The subsidy removing scenario 3 analysis showed that water prices may increase dramatically in times of drought and revealed the following: water suppliers would not be able to cover a majority of their costs when water sales are no longer possible during droughts (since water prices would be too high for farmers). Since water service providers would receive no subsidies from the government, it should be allowed[95] to set the market price above the marginal market price to generate profits. This increase in price would allow them to build a buffer in the form of reserves for times of fewer revenues caused by droughts. Those reserves would then help water suppliers to bridge decreasing sales-times on a market-based concept.

IPART announced that "water prices will be around 28 % higher in 2013/14 than in 2009/10" (IPART, 2010, p. 6) due to increasing costs of water suppliers and the expectation of less water sales (ibid., p. 6). This water price increase is not intended to remove subsidies from the government but indicates that suppliers' cost (C_{ws}) will increase in the future. This may be a result due to either an ailing and old network infrastructure or missed incentives for monopolists to decrease costs and invest in innovative technology. Hence, despite intended water price increases, these changes may not be high enough to fully cover costs of suppliers especially if their costs rise as well.

Water availability levels can change significantly within short periods of time in the MDB. Therefore, it is difficult to ex ante predict the exact volume of possible water sales, which would be essential to determine the full-cost-recovery water price. For this reason, the predefinition of water pricing might not be the right approach, facing frequent water availability changes as they occur in the MDB. A better solution might be a free market in which the water price reflects scarcity of water and in which allocation efficiency can easily be achieved by flexible, market driven water pricing. In this case, governmental intervention would not be necessary to allocate water in the most efficient way. Governmental intervention would only be meaningful to define volumes of extractable water, control water rights and prevent monopolists from over-dimensional profit maximisation.

Facing the fact that state governments in the MDB do not plan to change the approach of water pricing, the subsidy removing strategy has good potential to be implemented in the MDB and is in the opinion of the author a necessary step towards allocation efficiency and sustainable water usage.

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[95] By the independent institutions which suggest prices, water service providers are allowed to charge.

5.1.8.1.2 Conclusion of Scenario 3

In the past, one of the reasons for the observed over-consumption of water in the MDB was governmental failure. Inadequate water planning led to unsustainable water extraction levels. Additionally, a fixation of water-delivery-prices, which were too low, as well as subsidising water suppliers strengthened existing market inefficiencies.

The subsidy removing strategy is a cost-oriented approach that applies when independent institutions determine a water price that is meant to cover suppliers' costs and ideally allows a profit margin.

Finding a reasonable water price is difficult since it should, on the one hand, be high enough to cover total costs of suppliers and allow a profit margin to prepare for times of drought, and bridge revenue risks. On the other hand, the water price should not be set too high since this would remove cost-saving incentives for water service providers and would cause economic losses at the expense of irrigating farmers.

Exact prognoses of the impact, of full-cost-recovery pricing on irrigators are difficult since not all values and effects are quantifiable and the WatIM-Model analysis is limited to assumptions and constraints that constitute a segment of reality.

In consideration of these assumptions and constraints, the WatIM-Model analysis of scenario 3 shows that by introducing the subsidy removing policy, the impact on irrigating industries are quite small with a maximum crop production loss of 8 % in dry years and 0.5 % in wet years. This is due to the fact that in wet years, the water price experiences only slight increases since many water sales are able to cover suppliers' costs without significant increases to the water price. In dry years, water low value crops are not cultivated regardless of the water price when less than 2,000 GL/year water is available for irrigation. Hence, only impacts on water high value crops that are less water price elastic are observable. Consequently, production losses determined with the WatIM-Model are quite small. It can therefore be assumed that there is a high potential for water price increases, which are meant to fully cover suppliers' costs, especially when initial water price levels are low.

In conclusion, the introduction of a subsidy removing policy shows a low impact on irrigated agricultural production. It enables suppliers to fully cover their costs from water sales. Consequently, tax payers who previously paid for subsidies do not have to cover suppliers' costs anymore. In addition, externalities are internalised in the water price.

By removing subsidies that partly cover water suppliers' costs, the full-cost-recovery price is a convergence towards the "true" value of the private good water even though it still may not include externalities and opportunity costs completely.

5.1.8.2 Environment Compensating Irrigation Tax – Scenario 4

In the MDB, the water price derives from a predefinition from independent institutions, which take over water pricing. In the past, these water prices were inadequate and were not able to balance the supply and demand of water in the MDB. In Australia, prices for actual water deliveries are fixed for a longer period of time.

The consequence is that the water price is not adjusted to changing water availability and is consequently no indicator of water scarcity during droughts. This results in negative externalities and environmental damages occur when water is over-used.

The earmarked environment compensating irrigation tax is a Pigouvian tax with the aim to internalise external costs in the water price to prevent environmental damages and to provide an incentive to use water efficiently. Since the likelihood for environmental damages increase when water is scarce, the tax in the scenario 4 analysis is degressive. The tax rate $T\ (q_{w\ avail\ tax})$ increases with a decreasing level of water availability. By applying such a taxation system, water demand would decrease when water is scarce and water prices would increase due to the tax. This would solve the problem of over-consumption of water that occurred during the dry periods in the MDB, assuming that water prices are high enough being able to internalise externalities.

For the scenario analysis in this research, the author chose the following tax rates T which are applied at different levels of water availability ($q_{w\ avail\ tax}$):

In tax level 0 there is no tax applied when available water is 5,000 GL/year or above.

Tax level 1 (T = 19 % tax) is applied when available water is less than 5,000 GL/year or equals at least 2,500 GL/year,

Tax level 2 (T = 37 % tax) is applied when available water is less than 2,500 GL/year, or at least 1,500 GL/year, and

Tax level 3 (T = 45 % tax) is applied when available water is less than 1,500 GL/year.

Since a taxation system is not planned for the MDB by the government, these subdivisions are not based on real observed political propositions. Therefore, no experiences and knowledge are available about benefits and costs of the introduction of such an instrument. Furthermore, information on the externalities, benefits, costs or environmental damages as a result of irrigation is not available for the MDB. For those reasons, the author freely selected the above listed subdivisions for the scenario analysis, in this thesis, to generate knowledge about the potential economic impact on the irrigation crop industry. The differences between the rates of tax of the various levels are disproportionate and limited to the above mentioned four freely selected tax levels. Future research could focus on the analysis of proportional tax levels and their overall impacts.

To analyse the impact of the WMP of *environment compensating irrigation tax*, four example cases are observed as shown in Table 10.

Table 10: Scenario 4 example cases for different levels s of water availability and tax levels applied

	Available water in GL/year	**Tax applied**
Case A	6,024	Level 0 – no tax
Case B	4,500	Level 1 – 19 %
Case C	2,000	Level 2 – 37 %
Case D	1,223	Level 3 – 45 %

The water availability of 6,024 GL/year in Case A exceeds the range of availability levels at which taxes are applied. As Figure 42 illustrates, the WMP has no impact on crop production when water availability levels are that high, since no tax is applied. Crop production in level 0 equals the production of the reference wet year scenario in Subsection 5.1.7.1 (see Figure 24). In Case A, the reducing algorithm had to be applied until a water price of AU$ 60/ML, which is the same as in the reference wet year scenario.

Case B with a water availability of 4,500 GL/year is examplary for crop production in a level 1 wet year. To analyse effects of the *environment compensating irrigation tax*, produced quantities were first calculated for different price levels from AU$ 10/ML to AU$ 860/ML (without applying any tax) in AU$ 50/ML-steps and then calculated for water prices, which include the tax of 19 % from AU$ 11.90/ML to AU$ 1,023.40/ML. Crop production at 4,500 GL/year of available water and a 19 % tax applied is shown in Figure 39.

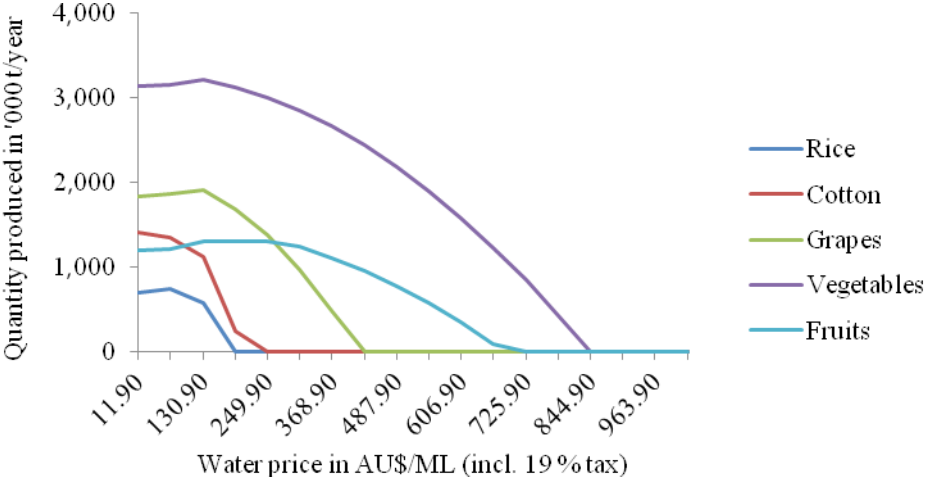

Figure 39: Crop production at a water availability of 4,500 GL/year and tax level 1 (19 %) applied

At water prices below AU$ 131/ML (including tax) the reducing algorithm had to be applied because optimal production would lead to the over-consumption of water. All crops are cultivated but with varying intensity. Rice is only produced until a water price of AU$ 190/ML (including tax) and has the lowest output of all observed crops. The low value crop cotton is produced until the water price reaches AU$ 250/ML (including tax). High value crops are also produced at higher prices. Vegetables have the highest production quantities and are cultivated until a water price of AU$ 845/ML (including tax).

Comparisons were made between production at water prices including the 19 % tax and without the applied tax. To allow the calculation of percentage changes, quantities produced at all observed water prices were totaled. At a water availability of 4,500 GL/year the environment compensating irrigation tax of 19 % leads to a decreasing production of all crops.

Since water low value crops are not produced at higher prices, even without applied tax, the impact of a tax on crop production for those low value crops are not observable for higher water prices. For this reason, the average percentage changes of crop production for these water low value crops are smaller than for water high value crops. Rice production shows the lowest production loss of 9.9 % followed by cotton production of 13.8 %. In cases of water high value crops, the impact of the policy is quite small when water prices (including tax) are very low. The higher the water price, the higher the observable impact on the production of high value crops. The average percentage loss for the production of grapes is 15.3 %, for vegetables 15.6 %, and for fruits 15.5 % as illustrated in Figure 42.

In Case C, the environment compensating irrigation tax is 37 % and water availability ($q_{w\ avail\ tax}$) is 2,000 GL/year, which represents a level 2 dry year. The reducing algorithm was applied until a tax including water price of AU$ 192/ML.

As Figure 40 illustrates, the low value crop rice is not produced at all. Cotton is least produced and production stops at a water price of AU$ 219/ML (including tax). Vegetable production is highest at all water prices and is produced until a water price of AU$ 904/ML (including tax).

To determine production losses due to the applied tax of 37 %, at a water availability of 2,000 GL/year, percentage changes were calculated in the exact way as in Case B. Quantities produced at all observed prices without the applied tax, are compared with quantities produced at all observed prices including the tax. Since rice is not produced at any water price, the WMP of environment compensating irrigation tax has no impact on the production of rice. All other crops are equally affected since average production losses are between 24.7 % and 26.5 % for cotton, grapes, vegetables, and fruits.

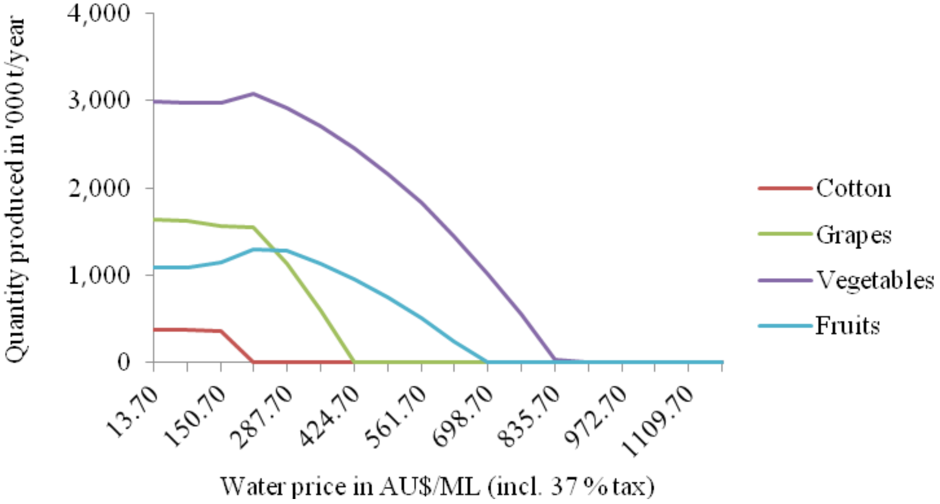

Figure 40: Crop production at a water availability of 2,000 GL/year and tax level 2 (37 %) applied

For tax level 3, where a tax rate of 45 % is applied, Case D with a water availability level ($q_{w\ avail\ tax}$) of 1,223 GL/year was chosen. In this case, the reducing algorithm was applied until a water price of AU$ 348/ML (including tax). The low value crops, rice and cotton, are not produced in very dry years at any water price level.

As Figure 41 illustrates, grape production is economically reasonable when the water price including tax is below AU$ 449/ML. The same applies for fruit production at water prices below AU$ 739/ML (including tax). As in Cases B and C, vegetables production is also highest, at all observed price levels, in very dry years. Vegetable production stops at a water price of AU$ 884/ML (including tax).

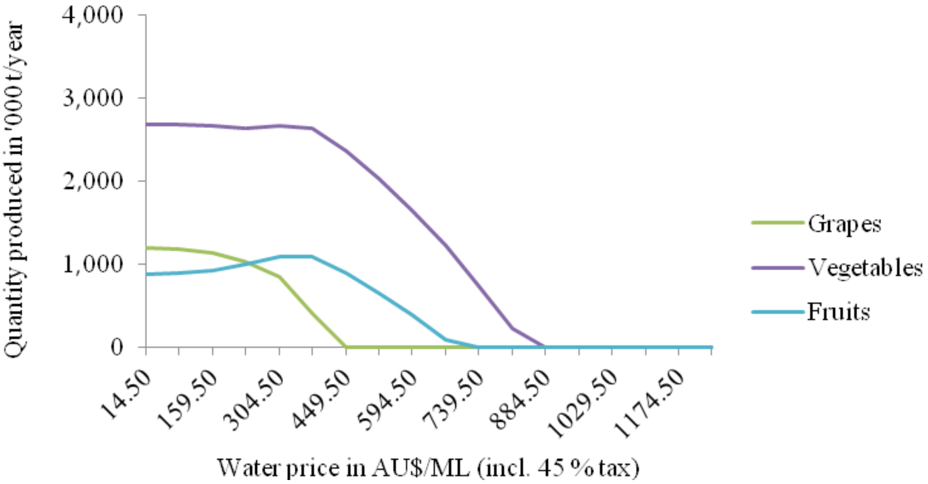

Figure 41: Crop production at a water availability of 1,223 GL/year and tax level 3 (45 %) applied

Since rice and cotton are not produced at a water availability of 1,223 GL/year independent of the water price, a Pigouvian tax has no influence on these low value crops. To calculate percentage production losses of grapes, vegetables and fruits, quantities produced at all price levels were totaled. This was done for the production at prices with and without the applied tax. The impact of the WMP on high value crops are very similar since average production losses for grapes, vegetables, and fruits are between 29.4 % and 30.4 % as shown in Figure 42.

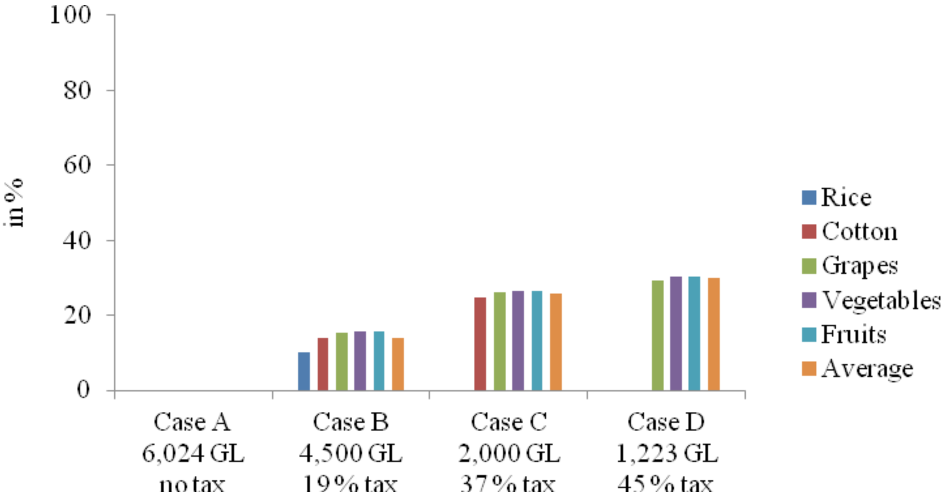

Figure 42: Average crop production losses at varying levels of water availability

This figure shows the average percentage losses of crop production due to the applied taxes at varying observed levels of water availability. Since quantities produced decrease on average by 0 % in Case A, 14 % in Case B, 26 % in Case C, and 30 % in Case D, it can be summarized that the impact of the environment compensating irrigation tax on crop production increases when water availability decreases. Higher water prices, which are coupled to lower water availability levels, might be problematic for farmers of perennials. They might not be able to afford higher prices during droughts. The consequence might be a cropping pattern change towards water independent dryland crops since even water high value crops are somewhat affected by the introduction of the tax in dry years.

To summarise, the *environment compensating irrigation tax,* which is linked to different water availability levels is an effective water pricing strategy to influence water consumption of agriculture. With the degressive subdivision according to water availability, water price development imitates free market mechanisms. With the introduction of an *environment compensating irrigation tax*, incentives for water savings, as a reaction to occurring droughts, can be given even though water-delivery-prices are fixed in the MDB for a longer period of time.

5.1.8.2.1 Potential of Pigouvian Taxation in the Rural Murray-Darling Basin

Information on externalities, benefits, costs, and environmental damages in the MDB are fundamental to establish reasonable tax rates $T\,(q_{w\ avail\ tax})$ which include those water use related aspects. Since this relevant information is limited in the MDB, it is difficult to find efficient taxation rates.

For the implementation of such instrument in the MDB, all available and recent information, knowledge, and scientific cognitions on the impact of crop irrigation must be taken into account. By controlling and monitoring the process of developing a suitable tax rate, it can be determined, whether the aim of finding a tax rate that equals the external marginal costs can be achieved or whether the tax rate needs to be adjusted.

Since the tax rate of this Pigouvian tax depends on the level of water availability, the water tax rate may vary often due to the inconsistency of available water. Therefore, the tax level must be adjusted frequently to the according level of water availability. This may enlarge high transaction costs and lead to uncertainties for investments and farmers' cropping decisions.

The Pigouvian environment compensating irrigation tax developed for this research is high during droughts and low during wetter years. This tax does not exist in Australia at the moment nor is it being seriously considered today. Nevertheless, the Parliament of the Commonwealth of Australia is aware of advantages of such a tax system. It stated that such a system would "provide incentives to encourage investment in efficiency improvements that provide environmental benefits or transfer of water […]" (The Parliament of the Commonwealth of Australia, 2011, p. 134).

The author has included this pricing policy in her analysis because she is convinced that it could be an efficient alternative to the quantitative strategies. These not only limit water consumption on a mandatory (in the case of the Basin Plan) or more or less voluntary basis (in the case of the RtB program) but are also very cost intensive and cause external costs. Hence, a Pigouvian tax strategy would be a market-based instrument to sustainably manage water demand by internalising externalities.

However, it is important to establish an environment compensating irrigation tax that is earmarked. Tax revenues should be directly used (and spent) by the government to compensate the environment for water losses and occurring damages that are a result of irrigation activities.

5.1.8.2.2 Conclusion of Scenario 4

The water price for water deliveries is not free in the MDB. It is predefined and fixed for a longer period of time. In the past, the water price charged did not reflect the "true" economic value of water as a natural resource, the opportunity costs, or fully cover the suppliers' costs. In combination with announcing water extraction levels that were too high, water was over-consumed in the past. As a consequence, environmental damages and external costs occurred.

A Pigouvian tax system internalises external effects, when applied properly, under the condition that taxes equal external marginal costs. This instrument provides an incentive to efficiently use water by giving the private commodity water the "right" price including all above-mentioned costs when full information about external marginal costs exists. This would allow an efficient allocation of water to the highest valued user.

However, exact prognoses about the impact of the environment compensating irrigation tax on irrigators are difficult, since information about externalities, benefits and costs is incomplete, and the WatIM-Model analysis is limited to earlier mentioned assumptions and constraints. Scenario 4 results should therefore be used with caution and are only intended to provide an overview about a possible impact that *could* arise under the made assumptions and constraints when a Pigouvian tax is implemented in the MDB. The potential WMP analysed in scenario 4 showed a significant impact on the irrigation sector in the MDB. The lower the water availability and the higher the tax rate, the more affect it has on irrigated crop production. The analyses of example cases showed that when a 45 % tax was introduced at a water availability of 1,223 GL/year, average production losses of 30 % could be expected. The higher the initial water prices are and the lower the water availability, the more severe the impact is on irrigated crop production.

In times of drought, the environment compensating irrigation tax would cause severe production losses for high value crops as well since farmers might not be able to afford the higher water prices. Consequently, cropping patterns might change towards irrigation water independent dryland cropping that reduces agricultural water consumption in the long-term.

In conclusion, the introduction of the environment compensating irrigation tax could help to achieve the goal of preventing over-consumption of water and environmental damages by internalising externalities. However, it may cause high production losses in times of drought and creates uncertainties regarding planning for investments and the next cropping season.

5.1.9 Comparison of Impacts

To be able to compare the effectiveness and the degree of impact the different WMPs have on irrigated agricultural production in the MDB, it is useful to provide an overview that illustrates the findings of the analysed non-pricing and pricing strategies. For this reason, different water availability levels were compared with the corresponding minimal sustainability water prices for each WMP. Furthermore, total volume of water applied under irrigated crop production is summarised to give an overview about different WMPs and their impact on water consumption. Thereafter, irrigated crop production and production losses under the different scenarios are compared. Finally, the impacts of the WMPs on profits for each crop industry are determined.

5.1.9.1 Comparison of Water Availability and Sustainable Water Price Minimum

Sustainable water availability is the maximum limit of extractable water (cap), which is defined by the WMPs and varies significantly between analysed scenarios.

Figure 43 shows scenarios analysed in Subsections 5.1.7 and 5.1.8 as well as the according levels of water availability, which is the basis for all results calculated by the WatIM-Model.

Excluded from comparisons in this subsection is the water sharing plan scenario 1 (dry year) where irrigation is not possible due to a water availability of zero GL/year. Also not included is the subsidy removing scenario 3 since only one water price is determined to cover suppliers' costs at a given level of water availability.

Since the comparison below aims to clarify the correlation between water availability and the minimum water price (which assumes that many water price levels were examined), a comparison with the subsidy removing scenario 3 is not possible in this case.

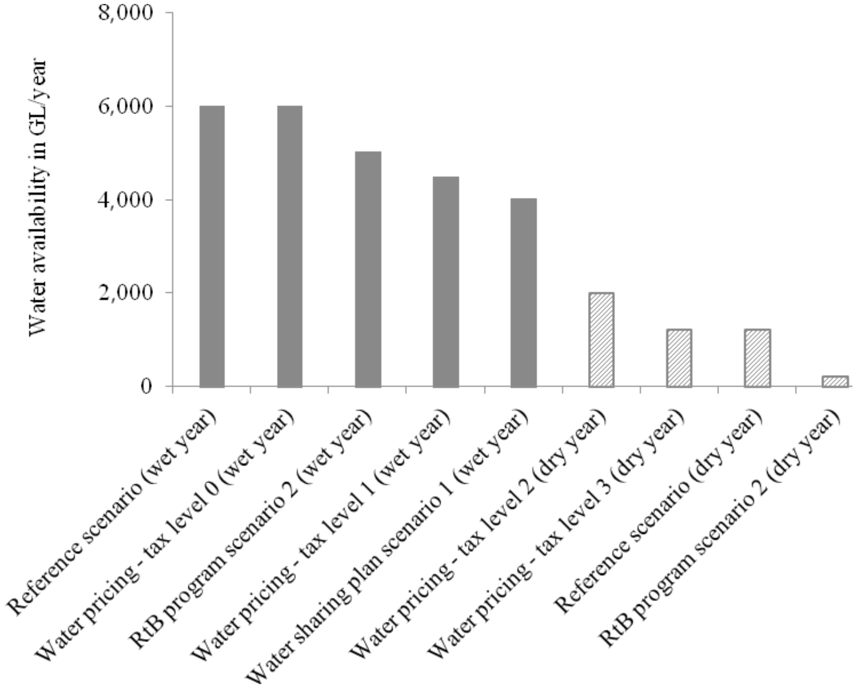

Figure 43: Overview of water availability of analysed scenarios

Water availability of the considered scenarios is highest in the reference scenario (wet year) and the water pricing – tax level 0 (wet year) scenario with

6,024 GL/year as Figure 43 shows. The lowest maximum cap is 223 GL/year for the RtB program scenario 2 (dry year).

Depending on varying levels of water availability, there are different sustainable water price minimums. Aiming for profit maximization, under optimal production, water consumption might exceed the maximum volume of extractable water at low prices. The sustainable water price minimum is the price where water consumption, under optimal production, equals the volume of water availability. It is also the water price up to which the reducing algorithm (see Subsection 5.1.6) of the WatIM-Model has to be applied. At higher water prices, optimal production equals sustainable production. Figure 44 shows the water price minimum for the analysed scenarios.

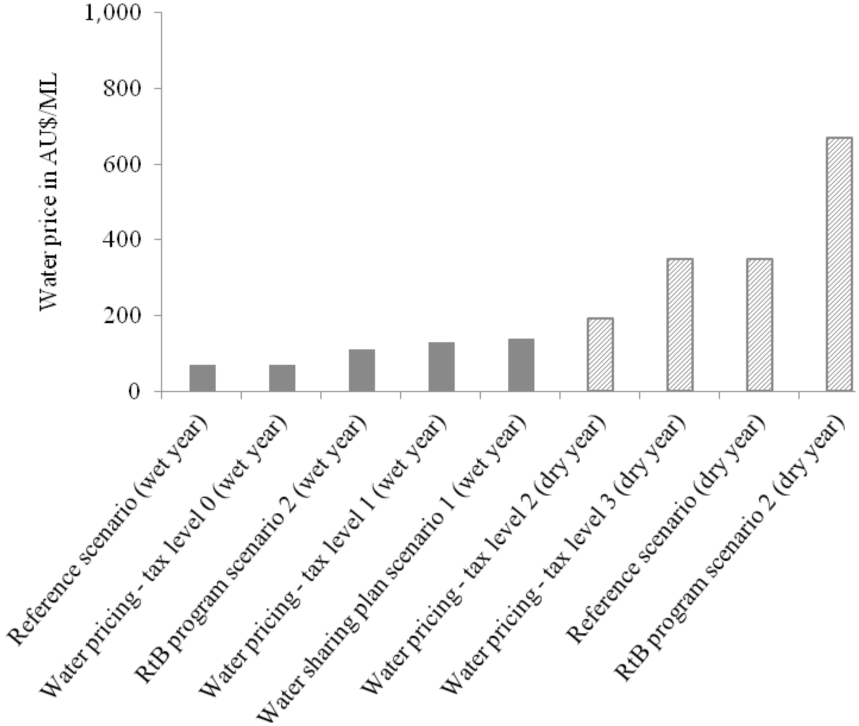

Figure 44: Overview of sustainable water price minimums

The lowest sustainable water price minimum is AU$ 70/ML and arises from the wet year reference scenario and the water pricing – tax level 0 scenario. In contrast, in the dry year RtB program scenario 2, the water price has to be at least AU$ 670/ML to be sustainable. Prices below these levels would result in water over-consumption if the reducing algorithm of the WatIM-Model is not applied. Hence, sustainable water prices depend on water availability, which varies under different water management strategies.

By comparing Figure 43 and Figure 44, a strong correlation between water availability and the sustainable minimum water price can be identified. The wet year reference scenario and water pricing – tax level 0 scenario have the highest amount of available water and the lowest sustainable water price minimum. In contrary, the dry year RtB program scenario 2 has the lowest volume of extractable water but the highest sustainable water price minimum. It can be concluded that the lower the sustainable level of water availability the higher the sustainable water price minimum up to which the reducing algorithm has to be applied to avoid over-consumption.

Percentage changes of water availability and changes of the water price minimum vary at different levels of water availability. For instance, a decreasing water availability of 17 % from 6,024 GL/year (wet year reference scenario) to 5,024 GL/year (wet year RtB program scenario 2) is accompanied by a water price increase of 57 % from AU$ 70/ML to AU$ 110/ML. Contrarily, a water availability decrease of 82 % from 1,223 GL/year in the dry year reference scenario to 223 GL/year in the dry year RtB program scenario 2 faces a corresponding increase of the water price minimum by 91 % from AU$ 350/ML to AU$ 670/ML. Hence, the water availability does not decrease to the same extent as the water price increase. Consequently, slight changes in water availability can have a large impact on the minimum water price and the sustainability of water consumption.

5.1.9.2 Comparison of Water Consumption

Water consumption highly depends on actual water availability and varies significantly at different price levels. Since optimal crop production decreases when water prices increase, water consumption, which depends on the amount of crops produced, decreases as well. Figure 45 shows the aggregated water consumption of all crop markets for a majority of the observed scenarios. Data from the dry year water sharing plan scenario 1 is not displayed since water consumption, at all price levels is consistently zero. The water pricing subsidy removing scenario 3 is also not included. In this scenario, only one water price covers the water suppliers' costs. Since this approach differs significantly from the others, the scenario of subsidy removing is not compared with other scenarios in this section. Results of the water pricing subsidy removing scenario 3 are represented in Subsection 5.1.8.1.

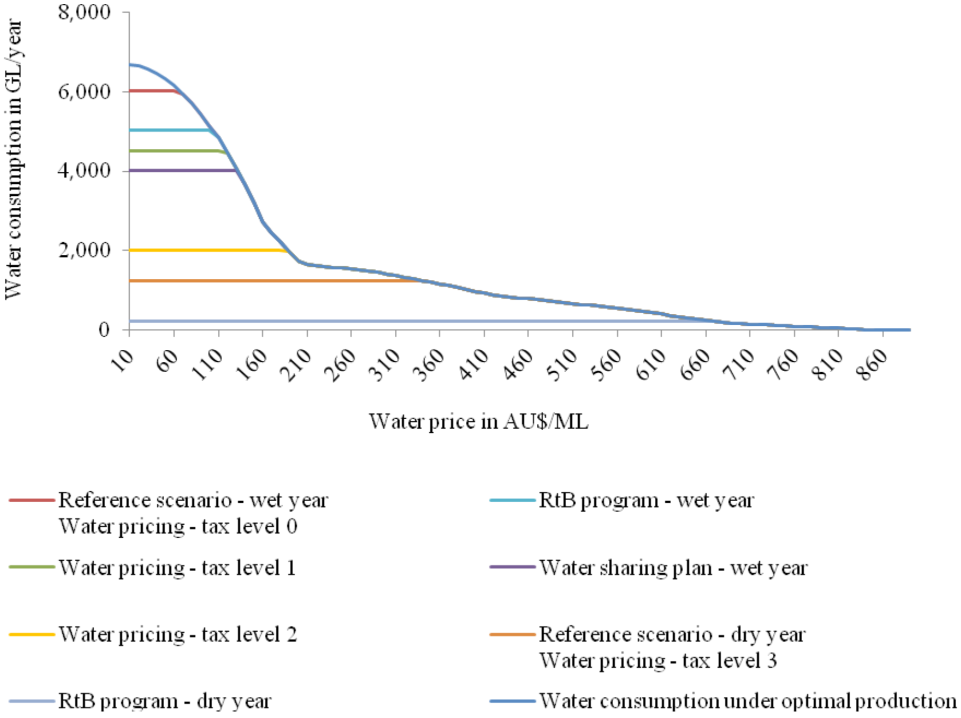

Figure 45: Aggregated sustainable water consumption – all scenarios

For each specified scenario, water consumption never exceeds the maximum level of water availability at any water price level. If water consumption, under optimal production, exceeds the sustainable level, the reducing algorithm of the WatIM-Model limits water consumption to the maximum volume available. More than likely, this could occur at very low water prices or at low levels of water availability. In these cases, water consumption remains constant at different water prices as shown in Figure 45. For example, in the wet year reference scenario, water consumption is constant at 6,024 GL/year until a water price of AU$ 70/ML. In the RtB program dry year scenario, water consumption remains constant at 223 GL/year up to a water price of AU$ 660/ML. The water price up to which water consumption remains constant is the sustainable water price minimum. In cases where the water price is below this minimum, water consumption under optimal production exceeds the volume of available water. To prevent over-consumption, the reducing algorithm is applied as already explained in the previous sections. At that sustainable water price minimum, the curves of water consumption of all scenarios merge into the curve of water consumption under optimal production. At prices of AU$ 670/ML and higher, water consumption of each scenario is the same. When the water price exceeds AU$ 840/ML, crop production is not possible anymore and no irrigation water is consumed in any scenario.

The more irrigation water is available in a scenario, the more water can be consumed in total. Water consumption is highest in the reference scenario wet year and the water pricing tax level 0, followed by the RtB program wet year. Water consumption is lowest in the RtB program dry year scenario. As Figure 45 shows, water consumptions of different scenarios vary only until a water price where both curves merge on the water consumption graph under optimal production.

The largest water savings, in dry years, are achieved by applying the water sharing plan strategy, since no water would be consumed for irrigation issues, followed by the RtB program, where water consumption is reduced to a maximum of 223 GL/year.

In wet years, the largest water savings can be gained by applying the water sharing plan policy since maximum water consumption is 4,064 GL.

The saved water is earmarked for the environment due to changes in the policy objectives from agricultural supporting to environmental protecting policies.

The true value of these water savings, for the environment, cannot be measured and are therefore constituted as uncertainties in this thesis.

5.1.9.3 Comparison of Production

The effects of the WMPs on agricultural production are intensively observed and discussed in the scenarios above. However, for overview reasons and comparative purposes, aggregated production of all five crop markets (rice, cotton, grapes, vegetables, and fruits) is illustrated in this section.

Following the division of wet and dry year scenarios, wet year comparisons are made between the wet year reference scenario, the wet year water sharing plan scenario 1, the wet year RtB program scenario 2, the water pricing – tax level 0, and the water pricing – tax level 1 scenario. Dry year scenario comparisons are carried out between the dry year reference scenario, the dry year water sharing plan scenario 1, the dry year RtB program scenario 2, the water pricing – tax level 2, and the water pricing – tax level 3 scenario.

Wet year

Since a certain volume of water is needed to produce one tonne of crop, the quantity produced is proportional to water consumption. Therefore, graphs of total aggregated crop production look very similar to the graphs of total aggregated water consumption. Crop production of different scenarios varies depending on water availability. At a water price of AU$ 140/ML and higher, optimal crop production is possible in every scenario. Therefore, production at higher water prices is the same in all scenarios. Figure 46 shows total aggregated crop production of all observed five crop markets in wet year scenarios.

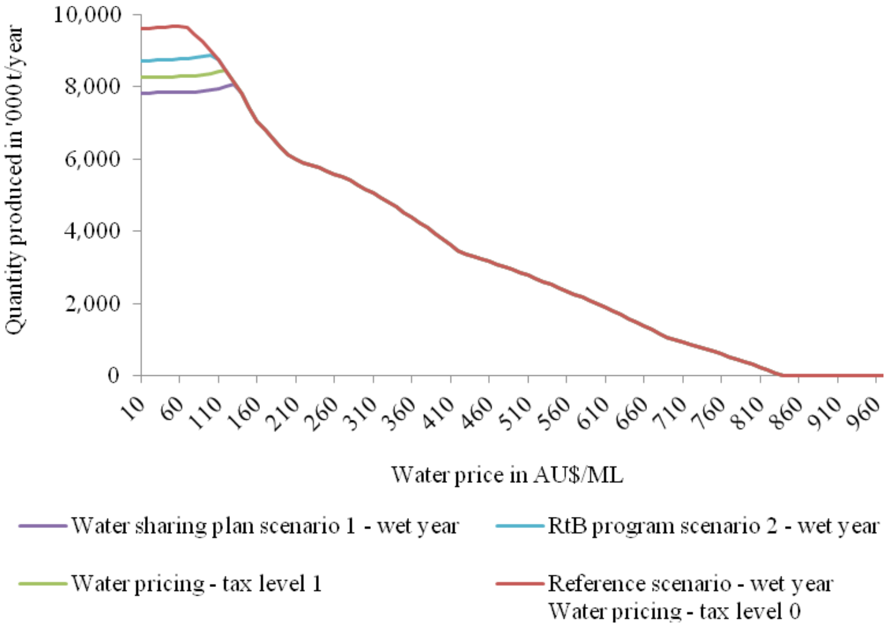

Figure 46: Total aggregated crop production – wet year

Highest production can be gained in the wet year reference scenario and the water pricing – tax level 0 scenario with a total aggregated crop production of 9,685,295 t/year. Total production of the other scenarios is lower since less water is applied. If the water price is lower than AU$ 140/ML, the least production occurs in the wet year water sharing plan scenario 1, with a maximum aggregated output of 7,831,490 t/year at a water price of AU$ 10/ML.

Total production of water low value crops (rice and cotton) and water high value crops (grapes, vegetables, and fruits) differs significantly. As Figure 47 and Figure 48 illustrate, the highest production of water low value crops is approximately 3,000,000 t/year and the highest production of water high value crops is approximately 6,600,000 t/year at low water prices, which is more than twice as much.

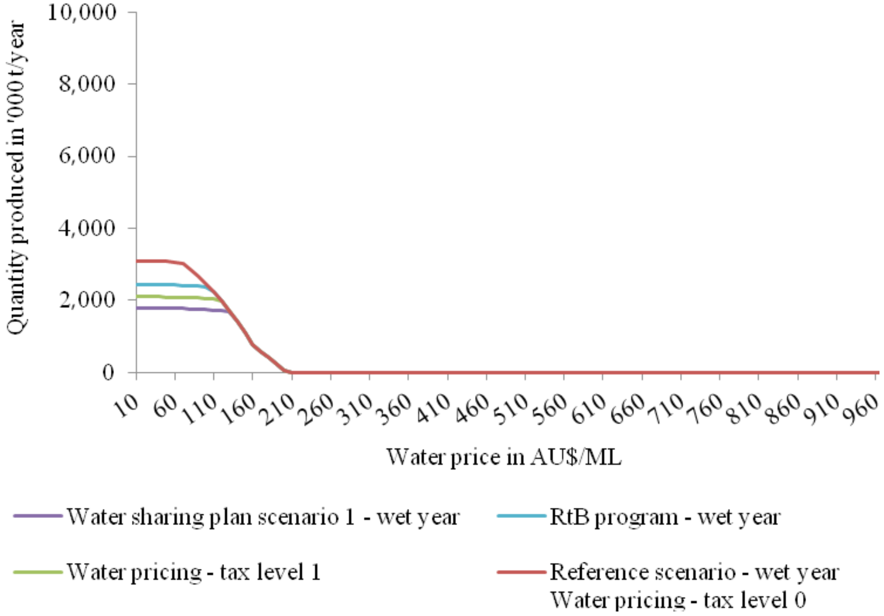

Figure 47: Aggregated crop production of water low value crops – wet year

The comparison of both crop groups clearly shows that the reaction of water low value crops on water price increases is stronger since production decreases rapidly towards zero and stops at a water price of AU$ 210/ML, in all wet year scenarios. Production of water high value crops decreases more slowly when water prices increase and is possible until a water price of AU$ 840/ML as Figure 48 shows.

Furthermore, as Figure 48 demonstrates, production of water high value crops does not vary much between observed scenarios. When comparing, for instance the wet year reference scenario outputs with the production under wet year water sharing plan scenario 1, at a water price of AU$ 10/ML, the difference of quantity produced is about 500,000 t/year. In contrast, the difference of low value crops at the same price is about 1,300,000 t/year.

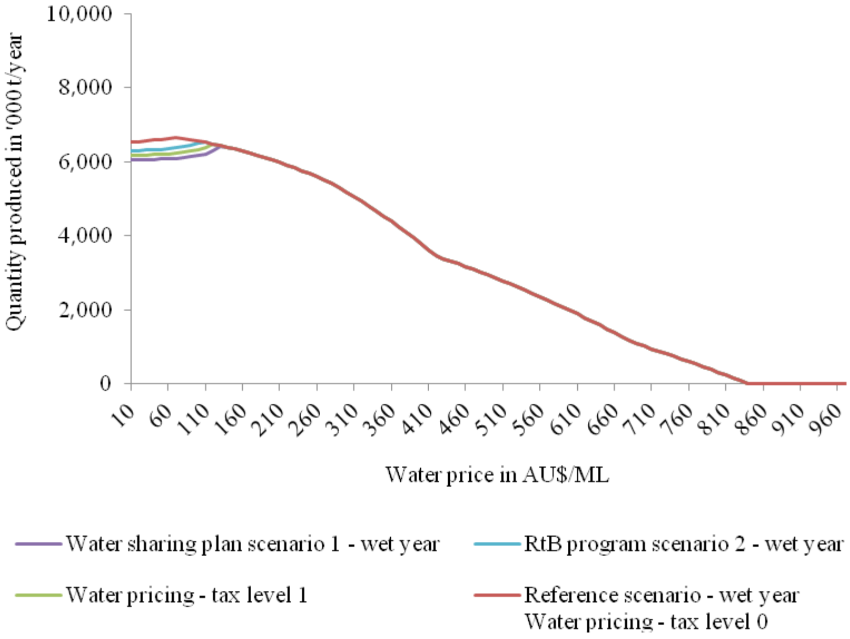

Figure 48: Aggregated crop production of water high value crops – wet year

Therefore, each introduced WMP has a different impact on the production of water low and water high value crops. The less water is available for a scenario and the higher the water price increases as a result of a water pricing strategy, the fewer crops can be produced.

Figure 49 illustrates the production losses that result from the introduction of all observed WMPs based on crop production in the wet year reference scenario at a water availability of 6,024 GL/year. Average production losses are determined by aggregating quantities produced at each observed price level and calculating the percentage change by comparing the aggregate of the reference scenario outputs and the aggregate of the WMP scenario outputs.

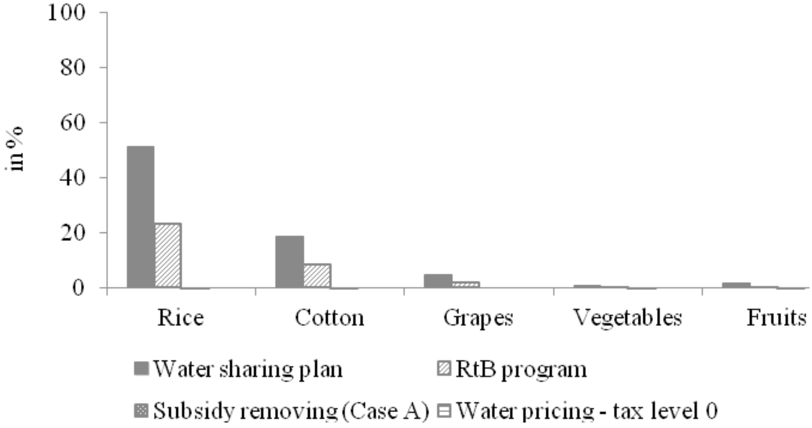

Figure 49: Average wet year production losses at a water availability level of 6,024 GL/year

The water sharing plan – scenario 1 results in the highest production losses of all crops. While rice production decreases by more than 50 % and cotton decreases by approximately 19 %, production losses of high value crops are less than 5 %. The impact of the RtB program – scenario 2 are highest on rice with a decreasing production of 23 %, cotton with a loss of 8 %, and a slight decrease of grape production of 2 %. Production of vegetables and fruits is not affected by this WMP. The subsidy removing scenario 3 (Case A) and the environment compensating irrigation tax – scenario 4 (Case A, no tax applied) lead to little or no production losses when comparing production losses at a water availability level of 6,024 GL/year.

In summary, while the introduction of the four observed WMPs primarily affects the production of water low value crops with losses of up to 51 % in wet years, water high value crops are only slightly affected. Major effects occur when quantitative non-pricing WMPs are applied. Water pricing strategies have virtually no negative impact on crop production in wet years.

However, effects of WMPs in wet years are relatively moderate compared to the effects on crop production in dry years.

Dry year

As in wet years, total aggregated crop production in dry years varies between different scenarios due to different volumes of water applied. At higher water prices, under optimal production, less water is consumed than there is available and therefore less output is generated. Therefore, crop production in all observed dry year scenarios is the same at a water price of AU$ 670/ML and higher as shown in Figure 50. Crop production is only possible at water prices below AU$ 850/ML.

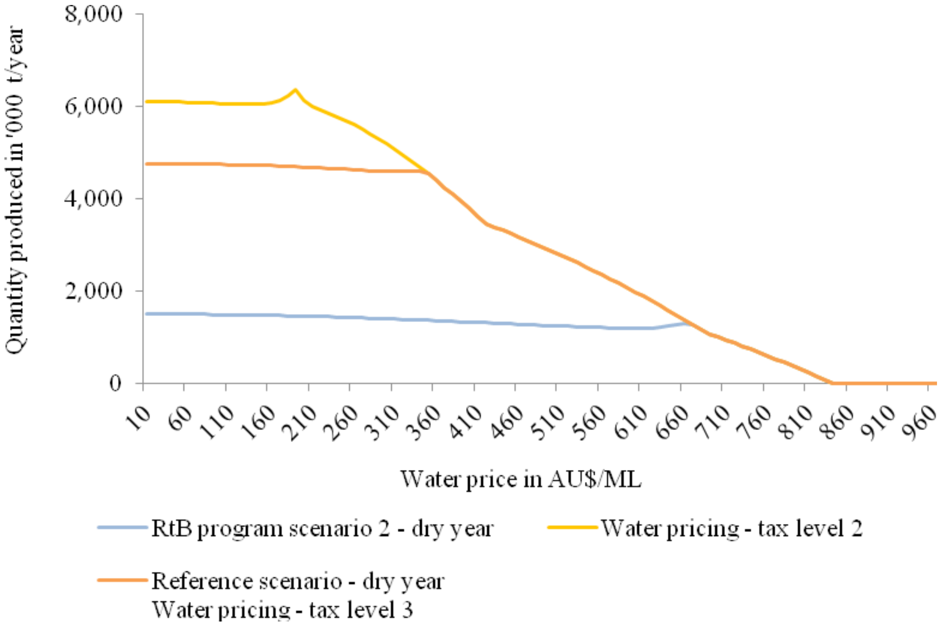

Figure 50: Total aggregated crop production – dry year

Highest crop production in the dry year reference scenario and the water pricing – tax level 3 scenario is 4,757,656 t/year at a water price of AU$ 10/ML and a water availability of 1,223 GL/year. Since there is even more water (2,000 GL/year) available in the water pricing – tax level 2 scenario, crop production with 6,362,060 t/year at a water price of AU$ 190/ML is highest of all the observed dry year scenarios.

The dry year water sharing plan scenario 1 is not included in this comparison, since there is no water available and irrigated crop production is not possible.

To show the difference between production of water low value crops (rice and cotton) and water high value crops (grapes, vegetables, and fruits) in the observed scenarios, crop production is separately shown in Figure 51 and Figure 52.

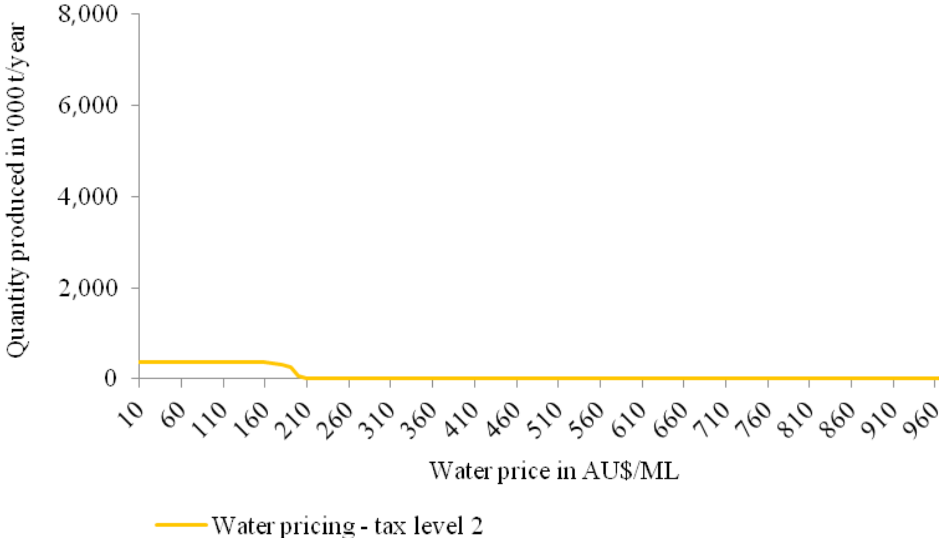

Figure 51: Aggregated crop production of water low value crops (rice and cotton) – dry year

As the figure above illustrates, cultivation of water low value crops is barely possible in the water pricing – tax level 2 scenario, with a maximum production of 378,479 t/year. In other scenarios production of rice and cotton is not possible at all, which shows that these crop kinds are highly affected by the introduction of the WMPs in times of drought.

Since there is so little production of low value crops, production of water high value crops more or less equals total aggregated crop production in dry years.

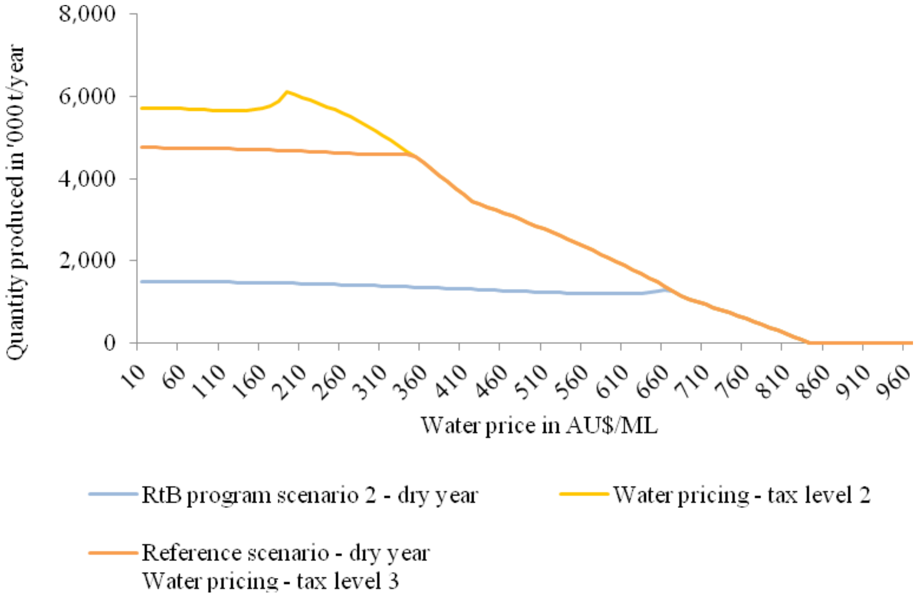

Figure 52: Aggregated crop production of water high value crops (grapes, vegetables and fruits) – dry year

Production output of water high value crops is highest in the water pricing – tax level 2 scenario, followed by the reference scenario – dry year and the water pricing – tax level 3 scenario. Quantity produced is lowest in the RtB program – scenario 2. In the water sharing plan scenario 1 – dry year, irrigated crop production is not possible at all.

As Figure 52 indicates, production of water high value crops varies significantly between observed scenarios. For example, when comparing produced quantities of the water pricing – tax level 2 scenario and the RtB program – scenario 2 at a water price of AU$ 10/ML, there is a difference of more than 4,000,000 t/year.

Due to varying levels of water availability and different water pricing strategies, production of water low value and water high value crops are affected differently by the introduction of the observed WMPs. Figure 53 illustrates average dry year production losses[96] based on a water availability of 1,223 GL/year (dry year reference scenario).

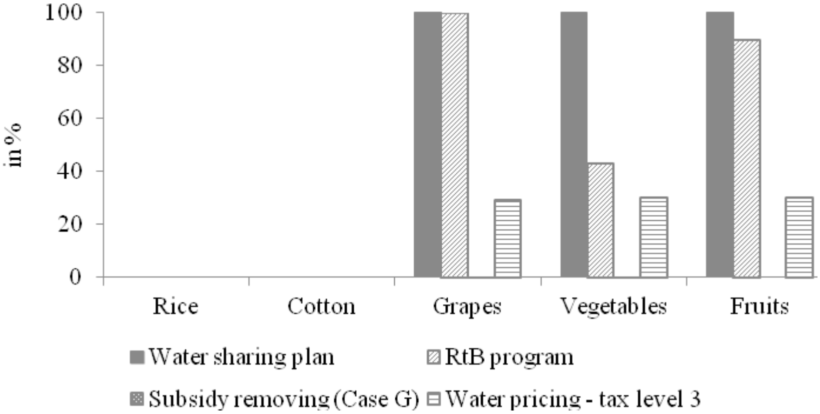

Figure 53: Average dry year production losses at a water availability level of 1,223 GL/year

On the basis of a water availability of 1,223 GL/year, production of water low value crops is not possible when applying any of the four observed WMPs. Since rice and cotton are not even produced in the dry year reference scenario, the introduction of WMPs has no impact on water low value crops and does not lead to production losses during dry years, when available water for irrigation is less than 2,000 GL/year.

All water high value crops are produced in the dry year reference scenario but not in the dry year water sharing plan scenario 1. Therefore, the introduction of this WMP leads to a water high value crops production loss of 100 %. The overall impact of the RtB program scenario 2 is considerable as well. There is a 100 % loss of grape production, 90 % loss of fruit production and a 43 % loss of vegetable production. The environment compensating irrigation tax – scenario 4 (Case D – tax level 3) results in a production loss of high value crops of approximately 30 %.

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[96] Average production losses are determined by aggregating quantities produced at each observed price level and calculating the percentage change by comparing the aggregate of the reference scenario outputs and the aggregate of the WMP scenario outputs.

The production of high value crops is least affected by the introduction of the subsidy removing scenario 3 (Case G) with a resulting production loss of less than 1 %.

Consequently, the impact of the WMPs can only be derived for water high value crops since water low value crops are not produced at all during droughts. Production losses for the irrigated grape, vegetable, and fruit industry are highest in dry years when applying quantitative non-pricing WMPs.

5.1.9.4 Comparison of Profits

As explained in the previous sections, the introductions of the WMPs in the WatIM-Model lead either to a reduction of available water for irrigation issues or to increased water prices. As a result, irrigated crop production is decreasing and cannot be as intensive as it would without the WMPs. This is accompanied by a reduction of the farmers' profits and causes therefore financial losses for the agricultural industry.

Generally, maximum possible profit under sustainable crop production is determined. Without applying the reducing algorithm, profit under optimal production would be highest when the water price is lowest and would decrease as water prices increase. By applying the reducing algorithm and limiting available water to a sustainable level, there are cases where water is re-allocated from one crop to another. As a result, profit derived from one crop decreases, while profit gained from another crop can increase with rising water prices. In the following, the profit derived from all observed crops is analysed separately.

Figure 54 shows the profits of the rice market, at varying water prices, for every scenario where rice production is possible. The profit in the wet year reference scenario and the water pricing – tax level 0 scenario is more or less constant at a profit of AU$ 1,543 million/year from water prices of AU$ 10/ML to AU$ 60/ML due to the reducing algorithm and constant maximum water consumption of 6,024 GL/year. At higher water prices, profits decrease with increasing water prices until the profit of the rice industry is zero at a water price of AU$ 170/

ML. This is the water price at which rice production is no longer possible in any scenario.

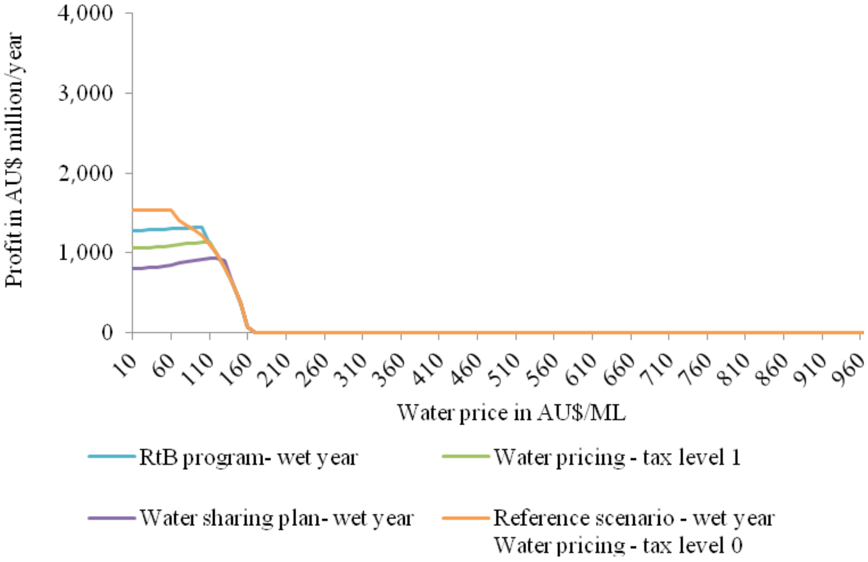

Figure 54: Maximum sustainable profit of the rice industry in various scenarios

The profit of the rice industry is consistently zero for any water price level in the dry year reference scenario, water pricing – tax level 3 scenario, the dry year RtB program scenario 2, the dry year water sharing plan scenario 1 and the water pricing – tax level 2 scenario and therefore is not included in the figure above. Hence, since rice production is not possible during droughts, WMPs do not lead to profit losses of the rice industry in dry years.

Maximum profit for the rice industry is AU$ 1,543 million/year at the lowest water price level of AU$ 10/ML in the wet year reference scenario.

In comparison to the reference scenario, profit in the wet year RtB program, the wet year water sharing plan and the water pricing – tax level 1 are generally lower but increase slightly until water prices are higher than AU$ 110/ML, due to re-allocation of water by the reducing algorithm. At higher prices, profits in all scenarios decrease rapidly and are zero when the water price exceeds AU$ 160/ML.

Compared to the wet year reference scenario, profit losses are highest in the wet year water sharing plan scenario 1, where the profit loss is AU$ 738 million/year (48 %) at a water price of AU$ 10/ML. Although not as severe, the rice industry is still significantly affected under the water pricing – tax level 1 scenario with the highest profit loss of AU$ 483 million/year (31 %) and the RtB program wet year with a loss of AU$ 260 million/year (17 %) at a water price of AU$ 10/ML.

Rice is the one crop that depends most on water, and its market price. As explained in Subsection 5.1.4, on average 1.49 ML irrigation water is needed to produce one tonne of rice. Since almost the equivalent volume of water (1.29 ML/ton) is needed for the production of cotton, similar profit losses can be identified for the cotton industry as the result of introducing the observed WMPs.

The highest sustainable profit of cotton farmers can be achieved in the wet year reference scenario and the water pricing – tax level 0 scenario with AU$ 2,532 million/year at the lowest water price level of AU$ 10/ML.

At this water price, profits gained in the RtB program wet year scenario, water pricing – tax level 1 scenario and water sharing plan wet year scenario 1 are only slightly lower with a maximum profit loss of 9 %. Due to far less water availability, cotton production is smaller, resulting in profit in the water pricing – tax level 2 scenario of only AU$ 898 million/year. Profit is zero in all scenarios when the water price is above AU$ 210/ML as shown in Figure 55.

The profit of cotton industry is consistently zero in the dry year reference, water pricing tax level 3, dry year RtB program and dry year water sharing plan scenarios and is therefore not included in the figure below.

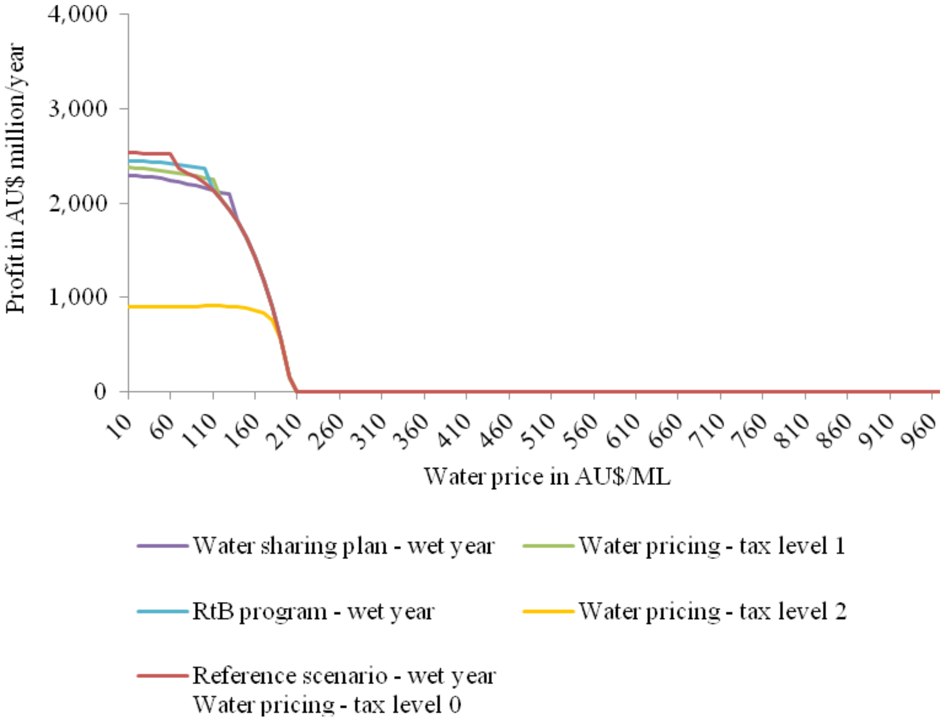

Figure 55: Maximum sustainable profit of the cotton industry in various scenarios

In contrast to the production of low value crops (rice and cotton), grape production is possible in all wet year scenarios and even in two dry year scenarios. Highest profits can be achieved in the reference scenario wet year and the water pricing tax level 0 scenario with AU$ 898 million/year at low water prices. At a water price level of AU$ 10/ML, profit losses under the WMPs of the wet year RtB program, the wet year water pricing – tax level 1 and water pricing – tax level 2 are a maximum of 5 %.

In the dry year reference scenario and the water pricing – tax level 3 scenario, far less irrigation water is available, however the maximum profits are still relatively high with AU$ 730 million/year at low water prices. Profits gained in all scenarios only slightly decrease until a water price of about AU$ 250/ML, where profits of all scenarios are more or less the same. At higher water prices, profits rapidly decrease and are zero when the water price is AU$ 430/ML. This is illustrated in Figure 56.

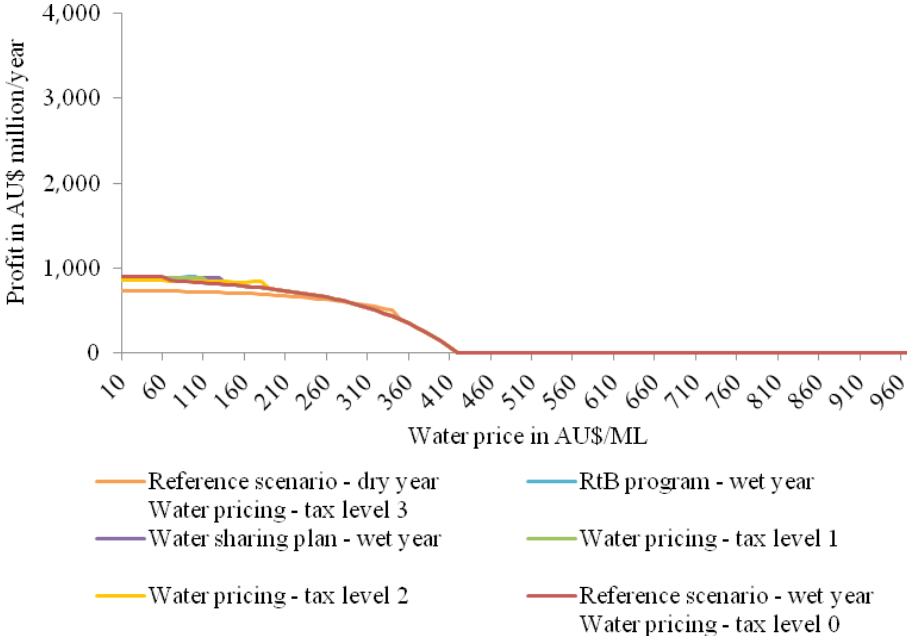

Figure 56: Maximum sustainable profit of the grape industry in various scenarios

In summary, the impact of the WMPs has very little effect on profits derived from grape production in wet years. In contrast, profit losses in dry years are high, specifically when applying non-pricing WMPs, since grape production is possible in the dry year reference scenario but not in the dry year RtB program and the dry year water sharing plan scenarios.

Vegetable production is possible in all observed scenarios except the dry year water sharing plan scenario. Maximum profits of approximately AU$ 3,263 million/year can be achieved at low water prices in the wet year reference scenario and the water pricing – tax level 0 scenario. Similarly, high profits can be gained in the wet year RtB program, the wet year water sharing plan scenario, the water pricing – tax level 1, the water pricing – tax level 2 and even in the dry year reference scenario as well as the water pricing – tax level 3 scenario (there is a much lower water availability in the latter two dry year scenarios). The maximum difference between those mentioned WMP scenarios and the applicable reference scenarios is less than 4 % as shown in Figure 57. Only profits derived from production in the dry year RtB program scenario are significantly lower with a highest profit of AU$ 2,258 million/year at a water price of AU$ 10/ML. This represents a decrease of 28 % compared to the dry year reference scenario. This results from the very low water availability in this scenario that also affects the most crops.

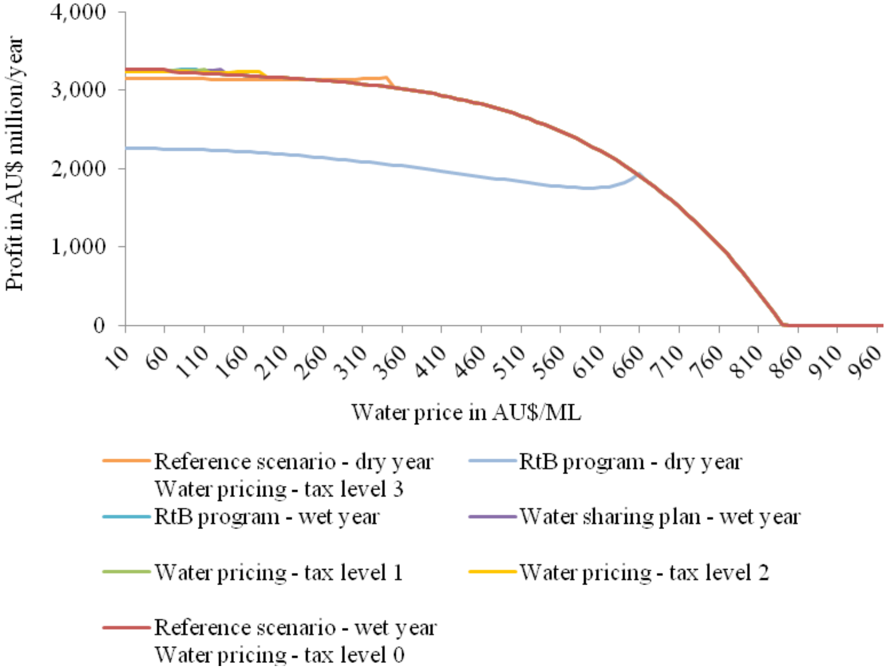

Figure 57: Maximum sustainable profit of the vegetable industry in various scenarios

Profits only decrease slightly until a water price of AU$ 400/ML in all scenarios (except in the dry year RtB program scenario). At this point, profits decrease rapidly and are zero when the water price is AU$ 840/ML. In the case of the dry year RtB program scenario, profit decreases slightly until a water price of AU$ 590/ML, then again increase due to re-allocation processes until a price of AU$ 660/ML, and decreasing rapidly when the water price exceeds AU$ 660/ML.

In conclusion, the observed WMPs have no significant impact on vegetable production during wet years. The highest impact is seen in the water sharing plan scenario in dry years, since vegetable production is not possible and profits cannot be derived. Under the dry year RtB program, vegetable production is possible but this WMP leads to considerable profit losses as illustrated in Figure 57.

Similar to the development of profits gained from vegetable production, are profits derived from the fruit market. As in the case of vegetables, the dry year water sharing plan is the only scenario where fruit production is not possible and therefore no profits can be realised. As illustrated in Figure 58, the wet year reference scenario and the water pricing – tax level 0 scenario, wet year RtB program, wet year water sharing plan, water pricing – tax level 1, and water pricing – tax level 2 have more or less the same development of profits at observed water price levels. At low water prices, a maximum profit of approximately AU$ 1.8 million/year is possible in these scenarios. At higher water prices, profits slowly decrease and are zero when the water prices are higher than AU$ 680/ML.

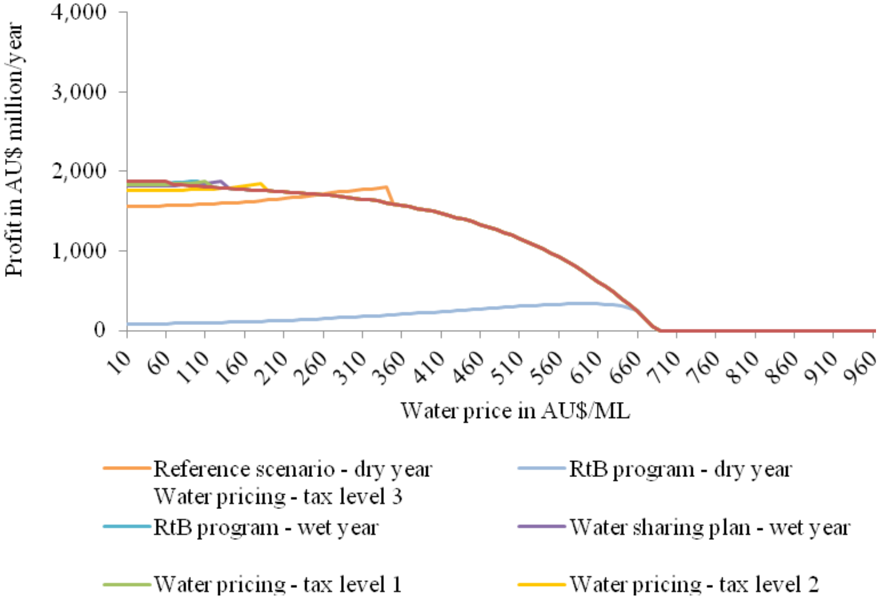

Figure 58: Maximum sustainable profit of the fruit industry in various scenarios

Figure 58 shows that profit from fruit production almost always increases with increasing water prices until sustainable profit equals optimal profit (e. g. in the case of the dry year RtB program until a water price of AU$ 640/ML). This can be explained by the fact that water is re-allocated from other crop markets for the benefit of fruit production. This allows the conclusion that the efficiency to cultivate crops shifts from other crops to fruits with increasing water prices. This is particularly true in the dry year RtB program scenario, where water is clearly re-allocated from vegetables to fruits as Figure 35 in Subsection 5.1.7.3 shows.

Profits gained from fruit production in the dry year reference scenario and the water pricing – tax level 3 scenario are AU$ 1,566 million/year at a water price of AU$ 10/ML, which is approximately 16 % lower compared to profits gained in the wet year scenarios. Based on the dry year reference scenario, there is a profit loss of 95 % at a water price of AU$ 10/ML when introducing the RtB program in dry years. Profits of the dry year reference scenario and the water pricing – tax level 3 scenario increase until a water price of AU$ 340/ML and are equal to profits gained in wet year scenarios at prices between AU$ 350/ML and AU$ 680/ML.

Profits of the dry year RtB program increase until a water price of AU$ 590/ML and are equal to profits gained in all other scenarios at prices higher than AU$ 660/ML.

In conclusion, the WMPs have very little impact on fruit production during wet years; however, the effects of the RtB program are very significant with high profit losses during dry years. The introduction of the water sharing plan leads to the highest profit losses in dry years, since fruit production is not possible at low levels of water availability.

5.1.10 Limitations of the Linear WatIM-Model

As explained in Subsection 1.3.2, a model is a theoretical construct that aims to reflect the complexity of reality including relationships and interdependencies as much as possible. This subsection points out limitations of the linear WatIM-Model regarding the accuracy of this theoretical construct.

The intention is to help to understand the results of the model and to prevent misinterpretations. Limitations suggest that further research is possible and that mathematical models can always be adapted and improved to more accurately reflect reality.

One limitation of the current WatIM-Model is that it is a partial equilibrium model and not a general equilibrium model. To include markets of other input factors, besides water, could help to better understand decisions regarding investments and cultivation periods.

Furthermore, the WatIM-Model is static and therefore unable to consider changes of time or forecasts. For future projections it would be important to include climate change into all examinations.

The model observes the impact of the WMPs on agricultural production of the five irrigated crop markets. A re-allocation of water or change of crop cultivation is limited to those markets. However, besides rice, cotton, grapes, vegetables, and fruits, are livestock (dairy farming) and pasture main water consumers in the MDB (Australian Bureau of Statistics, 2008b, Table 3.20). Therefore, an expansion to all crops that are already cultivated in the MDB or may have potential to be produced in the future is necessary. In particular, dryland cropping should be included in order to describe the input factor mobility between irrigated and dryland crops. The previous WatIM-Model simulations do not examine adaption processes of the farmers by changing cultivation from irrigated to dryland crops. In future this might be the most promising solution for farmers in the MDB when droughts become more severe and no water is available for irrigation issues or is so expensive that it is not efficient to cultivate irrigated crops any longer. When including crop change options, soil conditions must be taken into account since crops have different requirements. For instance, in the northern Basin, cotton, grains etc. are cultivated in black soil (high clay content), which is unsuitable for a majority of the vegetable crops.

Furthermore, multiple crop rotations may be included since the soil moisture can still be used after annual irrigated crops are harvested (e. g. vegetables may be planted after rice to use residual soil moisture).

Another limitation is that the current WatIM-Model is on an annual basis. This might not be precise enough to determine the reasons for irrigated crop production, since seasonal fluctuations cannot be taken into consideration. However, this might be relevant when for example, at the beginning of a growing season little water is available and the decision is made not to cultivate annual crops such as rice and cotton. However, if in the middle of that growing season, a lot of rainfall increases water availability to the maximum, the annual average of water availability would not explain why certain annual crops were not cultivated despite the high water availability.

Moreover, there is no differentiation between catchments within the MDB. This would be important to reflect climatic differences within the Basin. Similarly, it would be important to simulate water right trading (across trading zones), which is not covered at this point by the model. By including water right trading and a differentiation between water price for deliveries, water prices for licences and trading prices is possible.

The WatIM-Model only differentiates between dry and wet years scenarios. "Normal" state of nature occurs quite rarely but could be additionally considered in the model, in future.

Furthermore, technological change is not included at the moment but plays an important role in reality. With water efficiency improvements, water can be saved without any major impact on crop production (e. g. potential technological change to e. g. drip irrigation). Additionally, no land use change is included in the current WatIM-Model since maximum crop production is limited. Potentials for land expansions are not included.

Enhancements of the model are possible by integrating a differentiation between ground and surface water sources and including the quality of water that is an important factor regarding salinity levels. Additionally, crop product trade is not included. However, local WMPs will have a significant impact on Australian imports and exports of crop products. This should be included in the model as well.

This list of limitations represents the main issues that need to be improved to enable the WatIM-Model to better reflect reality in further research.

5.2 Interim Conclusion

The linear WatIM-Model is a tool, by which different water management strategies can be simulated and their impact on irrigated agricultural crop production in the MDB detected. By using the same methodology and framework for various WMP-scenarios, a direct comparison of policy impacts is possible. Therefore, conclusions about the impact on irrigated crop production in the MDB with a holistic view, on different water management options, can be derived.

The WatIM-Model is a theoretic abstraction of the complex and real world. Based on the conceptual framework, the optimisation problem, constraints, and assumptions described at the beginning of this chapter, scenario analyses were carried out.

By the use of scenario analyses, the impact of the four selected WMPs (water sharing plans, RtB program, and the two water pricing strategies of subsidy removing and taxation), on agricultural production in the MDB, are examined. This quantitative approach provides information about possible adaptions, and developments of agricultural production as reaction to diverse non-pricing and pricing WMPs.

For comparative reasons, reference scenarios provide initial data without any WMP applied. All scenarios apply one WMP and show the impact on the five observed crop markets in dry years (representing drought) and wet years (representing best conditions in the MDB for agricultural production). Simulations determine changes of quantity produced, of the sustainable level of water consumption, and of profits as a response to either water availability changes or water price changes.

In all observed scenarios, data is determined for a range of water prices. The only exception is the subsidy removing water pricing scenario 3 that has a different approach to find a sustainable water price, which is able to fully cover the suppliers' costs.

Even though these WMPs have different approaches, they all have the goal to prevent over-consumption of irrigation water by agricultural production in the MDB. Either they reduce quantitatively available irrigation water or they regulate the level of the water price. The scenarios have proven that the observed instruments are effective and change water consumption to a sustainable level. The degree of change of water demand and irrigated crop production depends on the intensity of the modification of the initial situation in dependency on the volume of available water and the water price. The less water is made available for irrigation or the higher the water price is, the larger the impact on irrigated farming.

In all scenarios, the water reducing algorithm is applied to reduce water consumption to a sustainable level. When setting the goal of profit maximisation and ignoring sustainable levels of water consumption, water would be over-consumed in all scenarios. The constraint of limiting available water is the second step in the WatIM-Model simulations, where all five crop markets are connected on the water market. The first step, which is the optimisation of profit maximisation, is done for each market separately. In this way it is possible to see the difference between sustainable production (where the reducing algorithm is applied if water consumption exceeds sustainable limits) and optimal production.

The scenarios show that the difference between optimal and sustainable production decreases with increasing water prices. Each scenario depicts a sustainable water price minimum up to which the reducing algorithm must be applied.

During droughts, Australian farmers experience difficulties even though no additional water saving policy is applied, as simulated in the initial scenarios. For instance, in the dry year reference scenario, the water low value crops, rice and cotton, are not cultivated at all. Reducing water availability or increasing the water price, by the introduction of a WMP, will exacerbate the difficulties of the irrigation industry during droughts, which show the decreases in crop outputs and losses in profits even in the case of water high value crops. Those losses are highest in the case of the water sharing plan scenario followed by the RtB program. Consequently, non-pricing WMPs have the most severe impact on irrigated crop production regarding production and profit losses. However, those non-pricing strategies would reduce water consumption the most.

By applying the WMPs, the results of the WatIM-Model scenarios show that water consumption decreases and that water is re-allocated from less water productive crops to higher water productive ones. The result of this re-allocation process is that production of the annual crops rice and cotton, which are less water productive and therefore categorised as water low value crops, most often decrease to the benefit of the water high value and more water productive crops grapes, vegetables, and fruits. Therefore, water high value crops are less affected by the application of the WMPs. The same applies for the impact of increasing water prices. All scenarios show that the negative effects and output losses are smaller in the cases of water high value crops.

The reactions on the WMPs and on water price increases are higher for farmers of annual crops, with lower water productivities, since they are more flexible with their decisions (vegetables are very water productive and their demand for water is more water price inelastic). The short-term reaction for perennials is lower since it takes several years to reach maturity. Farmers are less flexible and have to irrigate plants, even during droughts, if they want to keep them alive.

The WatIM-Model impact analysis helps to verify whether state intervention is actually reasonable and necessary from an economic point of view. However, to actually evaluate the reasonability of a WMP, all benefits, including environmental, must be determined in measurable quantities as well. Then a cost-benefit-analysis could provide clarity about the usefulness of the WMPs from a normative perspective.

Consequently, the WatIM-Model results can provide information about the possible impact on irrigated agricultural business and quantify water savings, but they are not sufficient to actually verify the reasonability of the WMPs. Since the environmental benefits cannot be measured, further research will be needed to remove the uncertainties.

6 General Conclusion

The challenges brought about by the enormous fluctuations in water availability in the Murray-Darling Basin, in the past, led to the over-consumption of water and environmental problems despite existing institutional arrangements.

Water is a finite and polyvalent resource that is extremely vulnerable. Although it is classed as a multifunctional private good, for the purposes of this thesis, only the agricultural and environmental issues were addressed.

Whenever a life necessity resource is scarce, the need to manage and use it responsibly is of paramount importance. In the case of water, this is only achievable by a functioning water market that is designed to balance supply and demand. However, this thesis identified, from a theoretical point of view, cases of water market failure. It also indicated situations where governmental intervention might be able to correct these inadequacies, through the introduction of the regulation theory.

By applying a mixed method approach, this thesis contributes to the basis of knowledge on water management policies and their possible impact on the agricultural industry.

By using results from explorative expert interviews, the validity of the governmental interventions, in the Murray-Darling Basin, concerning the above-mentioned problems of inefficiencies, over-consumption, and environmental concerns were examined. This approach also helped to find the reason why existing regional interventions that were designed to achieve allocation efficiency, for the most part, were generally unsuccessful. As this research revealed, governmental and market failures were both responsible for these inefficiencies through the implementation of inadequate water planning, incorrect water pricing, and informational deficiencies. In addition, far too many water access entitlements were issued and the political focus did not concentrate on sustainable water consumption. Instead, it targeted the growth of the irrigated agricultural industry in this region.

The institutional arrangements addressing these problems in the Murray-Darling Basin were the existing RtB program, the water sharing plan (Basin Plan), which is now in the phase of implementation, and the two potential pricing strategies of subsidy removing and the *environment compensating irrigation tax*.

The economic impact of the water management policies on irrigated crop production was analysed by applying the WatIM-Model, developed by the author, using various scenarios that reflected different water availability levels, and focused on five irrigated crops (rice, cotton, grapes, vegetables, and fruits) that are cultivated in the MDB.

6.1 Key Results from the Economic Scenario Analysis

By applying the partial equilibrium WatIM-Model, it is possible to examine the impact of water management policies on specific crops and understand water consumption changes. The main findings gained from the mathematical impact analysis are summarised below.

Water consumption of the observed five crop industries, under optimal crop production, is a maximum of 6,669 GL/year without applying any institutional arrangement or limiting water availability in the MDB. The reducing algorithm limits water consumption to the sustainable level of 6,024 GL/year in wet years, and to 1,223 GL/year in dry years in the reference scenarios.

The non-pricing water management policies quantitatively reduce available irrigation water to a volume that presents the sustainable level of water extractions. The pricing policies regulate the level of the water prices by either removing the subsidies for water suppliers or raising a Pigouvian tax.

All water management policies are proven to be effective concerning a change of water consumption to a lower level. The degree of demand reduction depends on the intensity of modification of the initial situation regarding the volume of available water and the water price.

It was found that the water price should be at least AU$ 70/ML to mirror water availability that is highest in the wet year reference scenario. Water prices below that would result in over-consumption of water under optimal production and profit maximisation of irrigation farmers. The less water is available, the higher must be the water price. In all scenarios, the water reducing algorithm is applied at low water prices to limit water to a sustainable volume of extractions, which in turn limits possibilities of irrigated crop production. When applying water management policies, regarding cutbacks in water availability or/and the water price, the greater the changes, the larger the difference is between sustainable and optimal production.

Additionally, the scenario analysis shows that water is re-allocated from less water productive crops to higher water productive ones. The water low value crops rice and cotton are more impacted by the introduction of any water management policy and are not produced in dry years at all. Water high value crops, with higher water productivities, are less impacted by the introduction of non-pricing and pricing policies. Hence, vegetables show the least reaction (followed by fruits and grapes) to the applied institutional arrangements.

Furthermore, it is observable that mandatory, non-pricing water management policies have the most severe impact on irrigated crop production regarding production and profit losses, and reduce water consumption the most.

By differentiating between wet and dry years, the scope of the impact on farmers is recognizable. Since the impact is relatively moderate in wet years, the same policy shows enormous effects on crop industries in the MDB in times of drought. Major impact-differences between dry and wet years occur when quantitative non-pricing policies are applied.

In the following, four concluding questions are answered that summarize the outcome of the model. For further usage or evaluation of these statements, the model assumptions and limitations should be considered.

What are the best water management policies for the environment?

Since environmental benefits are not quantifiable in economic terms, the volume of water saved is used as an indicator to determine the best solution for the environment. The more water is saved and left to the environment, the more beneficial it will be. Hence, the water management policy that saves the most water for the environment is – from an environmental perspective – the best solution.

In dry years, the largest water savings are made in the water sharing plan scenario, in which agricultural water consumption is decreased to zero. Consequently, 1,233 GL/year more water is available for the environment in dry years. With a maximum water consumption of 223 GL/year, the RtB program is the scenario with the second highest water savings with 1,000 GL/year. Hence, during times of drought, the environment benefits the most from the non-pricing strategies, since they represent the most radical reductions in agricultural water usage.

In wet years, the largest water savings can be gained by applying the water sharing plan policy and reducing irrigation water consumption by 2,000 GL. The second highest water savings of 1,000 GL/year occur when the RtB program is applied, which has a maximum water consumption of 5,024 GL/year.

Consequently, the non-pricing policy of water sharing plan can be seen as the most sustainable solution regarding water savings.

Besides the indicator of water savings, the extent of prevention of over-consumption of water by including externalities in the water price determines the water management policy. This is considered the best for the environment. The environment compensating irrigation tax is reasonable to internalise externalities and reflect water scarcity. However, since uncertainties about the level of water scarcity and the extent of externalities exist, it is difficult to find an appropriate water price. Nevertheless, this pricing policy is the best solution for the environment regarding the inclusion of externalities in water prices.

As illustrated below, the most sustainable solutions have the largest impact on agricultural water users and require the farmers to adapt the most.

Which water management policy has the most impact on irrigated crop output?
Farmers and the environment can be seen as competing water users with the consequence that supporting one water user can only be realised at the expense of the other. Consequently, the water sharing plan policy, which provides the highest water savings for the environment, has the most significant negative impacts on irrigation industry.

In dry years, the impact analysis of water management policies on water low value crops is impossible since these crops are not cultivated in any dry year scenario. However, the highest production loss is a result of the water sharing plan policy since no irrigation is possible when applying this non-pricing water management policy. In comparison to the reference scenario, all water high value crops experience an output loss of 100 %.

In wet years, the introduction of the water sharing plan policy produces the highest production losses, for water low value crops, with 51 % for rice, and 19 % for the cotton industry. Production losses of water high value crops are comparably low with less than 5 % in wet years. Consequently, the most negative economic impact occurs in wet years for water low value crops using non-pricing, mandatory regulations.

Which water management policies have the least impact on irrigated crop output?
The environment compensating irrigation tax is raised degressively, which means that the tax rate increases as the volume of available water decreases. Since the water pricing – tax level 0 is applied when the water availability is 5,000 GL/year or above, this water management policy has no impact on irrigated industry at all when water is abundant.

Furthermore, the mandatory subsidy removing pricing policy has a small impact on irrigated crop production since production losses are only 0.5 % in wet years and in maximum 8 % in dry years.

What role does the water price play?
To avoid over-consumption and external effects, a reasonable water price must be chosen that also reflects water scarcity.

In each non-pricing scenario and in the taxation scenario, the impact on crop production and water consumption at different water price levels is examined. If the reducing algorithm is not applied, crop production decreases with increasing water prices, since production costs increase and it becomes less efficient to produce irrigation water dependent crops. Water low value crops with less water productivity, react stronger to water price increases than water high value crops. This explains why the rice and cotton industries' demand for water is more water price elastic. When the water price determination in a market is not free – as it is the case in Australia – the water price should not be lower than the sustainable water price that depends on water availability. It was found that these minimum sustainable water prices vary significantly between different water management policies, hence, water prices should not be fixed since water availability varies considerably in the MDB.

6.2 Limitations and Future Research

Since this thesis addresses the impact of water management policies on irrigated crop production, it was important to select crops that are water intensive and cultivated in the observed region of the Murray-Darling Basin. These crops were divided into water high and water low value crops, due to their varying water consumption and value produced. In future research, the scope could be enlarged to include other agricultural products such as livestock, dairy farming, and pastures that are also large water consumers in the Basin. As a consequence of climate change, it is predicted that even less water will be available, and that droughts will be more severe. For this reason, the perspective must be enlarged to reflect the factor mobility from irrigation to dryland farming.

Further research should focus not only on the quality of water, but also the differentiation between groundwater and surface water. This is important because salinity problems exist in the Murray-Darling Basin to a high degree, which diminishes the usability of water and increases its scarcity.

The concept of virtual water is worthy of consideration since it includes the impact of international trade and globalisation. This promotes the importance of the importation and the exportation of irrigated agricultural products, since the water used for irrigation cannot simultaneously be used for other purposes.

Four water management policies were examined in this thesis, including two non-pricing and two pricing strategies. However, there are a number of other water management measures, such as supply enhancing strategies, that could be incorporated into future research. Additionally, these strategies exist independently or in combination with each other. In this thesis, the water sharing plan and the RtB program were analysed separately, but in reality, the combination of these policies would result in a more profound impact on the agricultural industry.

In order to find alternative policy solutions to the existing non-pricing strategies, the author created two hypothetical pricing management policies.

The cost-oriented approach analysed the impact of a volumetric water pricing scheme to ensure that suppliers' costs can be met through the sale of water. Instead of using a single-part tariff structure, one could include a two-tariff system analysis, in the future, by differentiating between fixed and variable costs.

The environment compensating irrigation tax has variable tax rates (0 %, 19 %, 37 %, and 45 %) that are disproportionate and freely selected. Future research could focus on both proportional and disproportional taxation levels in order to compare the various impacts.

Since only water prices for the delivery of water are included in this thesis, the water right trading market has not been taken into consideration. Therefore, water prices on the trading market cannot be included in the farmers' cost curve because in times of drought, the water right trading prices can be very high. This would make a profound difference.

In future, the economic viewpoint, on the costs and benefits of water management policies and their relevance in Australia, must be expanded to make a provision for the ethical aspects.

Since water is such a vital resource it is essential that it be distributed in a fair and equitable manner. However, due to the fluctuating water availability in Australia, caused by the less predictable weather, it is not always easy to satisfy all interested parties, and consequently conflicts arise from water scarcities. Furthermore, these conflicts will certainly worsen as the demand for water increases due to man's insatiability (Höffe, 2007, p. 26 f.), and the projected population growth.

Due to varying perspectives, decisions regarding water management strategies can be viewed differently. While one interest group may benefit, another may not.

Ethic asks for the right decision, one that ensures accountability and can be justified (Rieken, 2003, p. 13). A decision always has to be made even if this sometimes results in no action being taken at all.

Future research may want to examine the impact of water management strategies on a broader scale, one that encompasses not only the agricultural sector, but all water users including indigenous people, future generations, and the environment.

Only by the inclusion of all these interested parties and the impact these policies have, is it possible to make an assessment regarding the meaningfulness of these water managing strategies.

6.3 Final Thoughts

It is interesting to note, that the very same situation described in the poem *My country* by the Australian poet Dorothea Mackellar is still as relevant today as it was in 1907. Australia will always present a challenge to its farmers and it is hoped that the policies and strategies enacted by the governments will ensure that water is used sustainably both now and in the future.

"Core of my heart, my country!
Her pitiless blue sky,
When sick at heart, around us,
We see the cattle die –
But then the grey clouds gather,
And we can bless again
The drumming of an army,
The steady, soaking rain."

Excerpts from *My country* (Mackellar, 2011).

This thesis shows that whenever governments intervene in the water markets and place emphasis on the environmental issues, other water users are severely affected. This is particularly true in the case of the agricultural industry, which has already had to deal with its fair share of hardships in times of drought.

Therefore, any decisions concerning these water management policies must try to improve the current situation, through the careful evaluation and consideration of the holistic effects they might have.

7 Appendices

7.1 Categorisation of Interviewed Experts

Interviewed experts and expert knowledge are differentiated according to Bogner and Menz as follows:

Table A-1: Categorisation of interviewed experts

		Expert group			Categorisation of expert knowledge		
Interview No.	**Interviewee anonymous**	**Voluntaristic experts**	**Constructivistic expert**	**Cognitive-sociological expert**	**Technical knowledge**	**Process expertise**	**Interpretive knowledge**
Scientists							
1	S1		x				x
2	S2		x				x
3	S3		x				x
4	S4		x				x
5	S5		x				x
6	S6a		x				x
6	S6b		x				x
6	S6c		x				x
7	S7		x				x
8	S7		x				x
Farmers' Representatives							
9	FR1a		x		x	x	
9	FR1b		x		x	x	
10	FR2		x		x	x	
Policy Maker							
11	PM1		x		x	x	
12	PM2		x		x	x	
Farmers							
13	F1			x	x	x	
14	F2			x	x	x	
Indigenous People							
16	I1	x				x	x

7.2 Data for the Estimation of Inverse Demand Functions

Data-Input for regression: water year 1994–95 to 2009–10

- Demand consumed Q in Australia in t/year (FAOSTAT, 2010b)
- Price for the commodity P (consumption price and supply price are assumed to be the same) in AU$/t (ABARES, 2011)
- Average Annual Earnings E (total Australian population) in AU$ million/year projected from the Average Weekly Earning per Person to the Average Annual Earnings for the whole Australian Population (Australian Bureau of Statistics, 2011a)
- Final Consumption Expenditures C (total Australian population) in AU$ million/year projected from the Final Consumption expenditure per capita to the Final Consumption expenditure for the whole Australian Population (Australian Bureau of Statistics, 2012a)
- Time in years $A = 16$ (years from 1995–2010)

Table A-2: Data set for the example of rice

Q	P	E	C	A	year
in t/year	**in AU$/t**	**in AU$ m/year**	**in AU$ m/year**		
181153	190	480900	417699	1	1995
198207	238	501173	431645	2	1996
324059	224	521494	443839	3	1997
331354	256	541806	464449	4	1998
405359	259	556552	487963	5	1999
424573	264	589118	508456	6	2000
443062	213	624110	526040	7	2001
469195	274	655265	541318	8	2002
403839	348	700541	563211	9	2003
428754	325	730948	591197	10	2004
432754	297	780880	617133	11	2005
426538	283	827549	635018	12	2006
416009	337	882825	663001	13	2007
405194	414	934302	694206	14	2008
375176	566	991840	694584	15	2009
436926	457	1057423	712182	16	2010
381385	309	711045	561996	9	Mean
469195	566	1057423	712182	16	Maximum
181153	190	480900	417699	1	Minimum
410684	279	677903	552265	9	Median

Source: own illustration, the source of data is explained above the table.

7.3 The Rejected Cobb-Douglas Model

The model development was performed according to the microeconomic modeling approach of Kirschke and Jechlitschka (2002).

Conceptual framework

In order for the Cobb-Douglas model to work, it is assumed that no protection policies are applied. In this context, world market prices are supposed to be equal to the domestic prices in the Cobb-Douglas model.

The supply function is:

$$q_m^s(p_n^s) = a_m(1 + f_m)(p_m^S)^{\varepsilon_m^S} \prod_{n=2}^{5} (p_n^S)^{\varepsilon_n^S}$$

with $m = 1$ and $n = 2, \ldots, 5$.

Each of the five markets, rice, cotton, grapes, vegetables, and fruits, have its own supply function $q^s(\cdot)$ and demand function $q^d(\cdot)$ depending on prices p in all markets. The parameter q^s is the quantity supplied.

The non-linear Cobb-Douglas model takes into account quantity changes on the market *m* due to price changes on all other markets *n*. Each market is not only influenced by itself, but by the other four markets as well, by the use of appropriate own-price and cross-price elasticities ε_{mn}. In this way, market interdependencies can be derived.

ε_{mn}^S is the supply elasticity and *f* is the exogenous shift parameter, which is used to simulate price policies in the first step.

a is the supply constant, defined for the initial equilibrium as:

$$a_m = \frac{q_m^S}{\prod_{m,n=1}^{5} (p_{mn}^S)^{\varepsilon_{mn}^S}}$$

The shift factor is the product of the percentage ratio of the costs for water to total costs (τ) in market m and the percentage change of the water price (σ).

$f_m = [(\tau_m 100^{-1})(\sigma 100^{-1})]$

As well as the supply function, the demand function is dependent on prices *p* in all markets *m* and additionally on income *y*:

$$q_m^d(p_n^d, y) = b_m \prod_{m,n=1}^{5} (p_{mn}^d)^{\varepsilon_{mn}^d} y^{\eta_m}$$

With *m,n* = 1,…, 5.

Where ε_{mn}^d is the demand elasticity, η_m is the income elasticity of demand on market m and *b* is the demand constant, defined for the initial equilibrium as:

$$b_m = \frac{q_m^d}{\prod_{m,n=1}^{5} (p_{mn}^d)^{\varepsilon_{mn}^d}}$$

The cost function of each market *m* is defined as:

$$C_m = p_m^S q_m^S (1 + f_m) - a_m (1 + f_m) \prod_{\substack{m,n=1 \\ n \neq m}}^{5} {p_m^S}^{\varepsilon_{nm}} \prod_{\substack{m,n=1 \\ n = m}}^{5} \frac{{p_m^S}^{\varepsilon_{nm}+1}}{\varepsilon_{nm} + 1}$$

with m,n=1,…, 5.

The shift parameter f_m is treated equally as in the supply function.

The Cobb-Douglas demand function would be infinite, as the integral value is ∞. Following Kirschke and Jechlitschka (2002), a fictitious intersection of the demand curve with the price axis is defined, which cut off the integral at an adequately high price[97] p_m^{d0} (Kirschke and Jechlitschka, 2002, p. 45). Therefore, the evaluation of the level of total benefit and other functions, which are based

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[97] This price is set at such a high level that it cannot be achieved in terms of stable currencies (this would not be true in hyperinflationary conditions).

on the total benefit such as consumer and producer surplus, must be done with caution (Kirschke and Jechlitschka, 2002, p. 49).

The total benefit is defined as:

$$TB_m = p_m^d q_m^d + b_m \prod_{\substack{m,n=1 \\ n \neq m}}^{5} {p_m^d}^{\varepsilon_{nm}} \prod_{\substack{m,n=1 \\ n = m}}^{5} \left(\frac{{p_m^{d_0}}^{\varepsilon_{nm}+1} - {p_m^d}^{\varepsilon_{nm}+1}}{\varepsilon_{nm}+1} \right) y^{\varepsilon_{ym}}$$

with m,n=1,…, 5.

Foreign exchange (FE) is defined as exported quantity derived by subtracting the quantity demanded from the quantity supplied multiplied by world market prices p^w for each market *m*:

$$FE_m = (q_m^s - q_m^d) p_m^w$$

Further, welfare for each market is gained by applying:

$$W_m = TB_m - C_m + FE_m$$

Total welfare is consequently: $TW = \sum_{m=1}^{5} W_m$

Total expenditures are $TEP^d = \sum_{m=1}^{5} p_m^d q_m^d$

Total revenue is $TRV^s = \sum_{m=1}^{5} p_m^s q_m^s$

Consumer surplus is total benefit less expenditures: $CS_m = TB_m - EP_m$

Producer surplus is revenue less costs: $PS_m = RV_m - C_m$

Economic variables are aggregated in the Cobb-Douglas model. Prices and quantities supplied and demanded are portrayed as mean values across the total MDB.

Limitations of the Cobb-Douglas Model

The Cobb-Douglas model has some significant deficiencies and was therefore rejected. On the one hand, insufficient data on elasticities that are the main constituents of the supply functions, demand functions, cost functions, and functions for total benefit, made it impossible to simulate realistic conditions with the Cobb-Douglas model. All other economic variables are dependent on these aforementioned functions and therefore own-price and cross-price elasticities, which show the importance of correct and realistic elasticities. Wheeler et al. (2008) state that it is difficult to estimate water price elasticity (Wheeler et al., 2008, p. 41). Brennan (2006) argued that "price response of the market to water availability is much more pronounced in years of low rainfall" (Brennan, 2006, p. 403). Hence, only water demand elasticities vary greatly and therefore cannot be used as a fixed exogenous parameter for the Cobb-Douglas model.

This absence of plausible elasticities, on the other hand, leads to insufficient sensitivity of the model. An increase of the water prices does not decrease crop production as significantly as it was expected and shown in reality.

The main deficit of the Cobb-Douglas model is that input-factors are not included in the model. The cost function only includes supply quantities, supply prices, and elasticities. It is indispensable, that water needs to be integrated as an input-factor into the model to see the impact of the WMPs, not only with the help of an exogenous variable but as a result solved within the model. It is essential to integrate the relation of the costs for water to the total costs and therefore input factors into the model.

The first idea was to integrate water as an explicit input market by adding the water market as a factor market. This would create a sixth market besides the crop markets. Then the factor market was thought to be interconnected to the other product markets by cross-price elasticities.

This idea was found to be inadequate since factor markets could not be integrated on one level with the product markets into the supply function because water is an input factor for the production markets. This approach is not useful for this thesis since the goal is to analyse the impacts of the WMPs (which have an influence on the availability of the input factor water or/and its prices) on crop production. Since the Cobb-Douglas approach suspects a substitution between the interconnected markets, it is assumed that the sixth factor market (which would be the water market) could be replaced by the first five product markets, which is not the case. Furthermore, the crops are not necessarily substitutes for each other. For instance, rice and cotton, or cotton and fruits cannot be substituted. Therefore, the Cobb-Douglas approach does not help to answer the third research question of this thesis concerning examine the economic effects WMPs may have on agricultural industry.

Because of these reasons, the author rejected the Cobb-Douglas model and chose to follow a linear model approach.

7.4 Sensitivity Analysis of the WatIM-Model

A sensitivity analysis was carried out to determine the impact of the different values of parameters on dependent variables within the model. The author tested the parameters a and b, in the inverse demand function (equation II) and the calibration factor in the cost function (which is specified in equation IV).

Profit function

$$\pi_m = p_m(q_m)q_m - C_m(q_m) \tag{I}$$

Inverse demand function

$$p_m(q_m) = a - bq_m \tag{II}$$

Cost function

$$C_m(q_m) = q_m(p_w q_{wm}\gamma + p_{rm}) \tag{III}$$

Specification of calibration factor

$$\gamma = p_w \varepsilon_m \tag{IV}$$

To test the sensitivity, changes are made one at a time, keeping all other parameters and values constant.

7.4.1 Saturation Quantity of the Demand Function

While keeping all other parameters constant, the parameter *saturation quantity of the demand function* (which is *a* in equation II) for each crop market was tested by assuming values between 0 and 5000.

$a \in \mathbb{N}_0 = \{0; 500; 1{,}000; \dots ; 4{,}500; \; 5{,}000\}$ $0 \geq a \leq 5{,}000$

The result of this analysis is illustrated in Figure A-1. For instance, the upper extreme of rice production is 3,095,666 t/year (when assuming the saturation quantity to be 5,000), the upper quartile is 2,262,333 t/year (when the saturation quantity is 4,000), the lower quartile is 0 t/year (when the saturation quantity is 1,000 or less) and the lower extreme is 0.

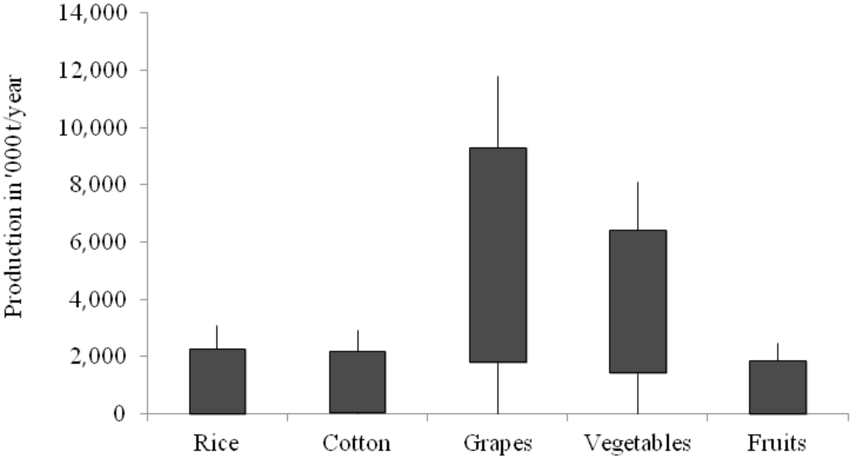

Figure A-1: Sensitivity analysis of saturation quantity of the demand curve

Table A-3: Sensitivity analysis of saturation quantity of the demand curve with higher and lower quartiles and extremes (in t/year)

Crop	Lower extreme	Lower quartile	Upper quartile	Upper extreme
Rice	0	0	2,262,333	3,095,667
Cotton	0	53,429	2,196,286	2,910,571
Grapes	0	1,789,300	9,289,300	11,789,300
Vegetables	0	1,423,200	6,423,200	8,089,867
Fruits	0	0	1,849,950	2,474,950

The largest impact on crop production has a variation of the saturation quantity of the demand curve for grape production. While changing the saturation quantity of the demand curve between 0 and 5,000, the crop production would vary between 0 and 11,789,300 t/year.

Hence, the parameter *saturation quantity of the demand curve* has a large impact on the dependent variable crop production in all markets.

7.4.2 Gradient of the Demand Curve

The parameter *gradient of the demand curve* (which is *b* in equation II), for each crop market was verified by assuming values between –0.0001 and –0.002.

$b \in \mathbb{Q} = b\sim\sim = \{-0.0001, -0.0002, \ldots, -0.002\} \qquad -0.002 \geq b \leq -0.0001$

While keeping all the other parameters constant, the result of the test is shown in Figure A-2.

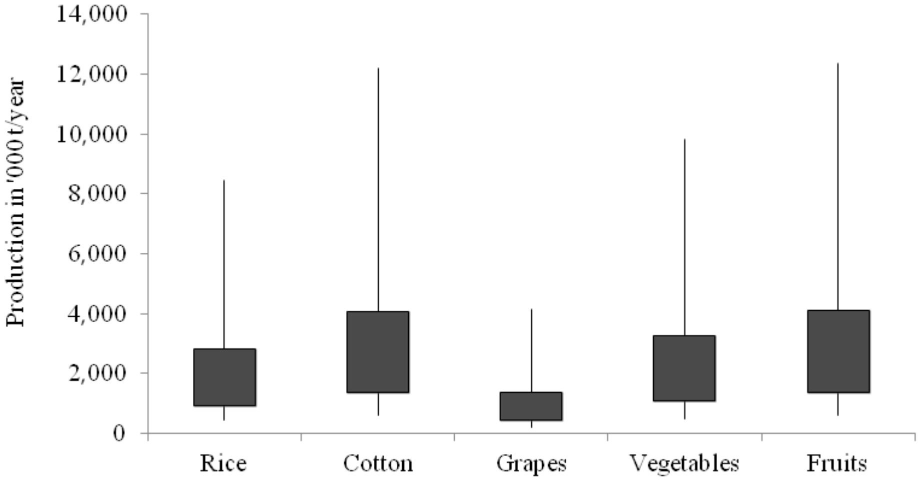

Figure A-2: Sensitivity analysis of the gradient of the demand curve

Table A-4: Sensitivity analysis of the gradient of the demand curve with higher and lower quartiles and extremes (in t/year)

Crop	Lower extreme	Lower quartile	Upper quartile	Upper extreme
Rice	422,200	938,222	2,814,667	8,444,000
Cotton	609,950	1,355,444	4,066,333	12,199,000
Grapes	207,680	461,511	1,384,533	4,153,600
Vegetables	492,230	1,093,844	3,281,533	9,844,600
Fruits	617,980	1,373,289	4,119,867	12,359,600

The production variables on all the markets are highly affected by the variation of the gradient of the demand curve. However, the highest contrast in crop production occurs for cotton and fruit production when changing the gradient of the demand curve. If the gradient of the demand curve is –0.002, crop production would be 609,950 t/year (cotton) or 617,980 t/year (fruit). If the gradient of the demand curve is –0.0001, crop production would be 12,199,000 t/year (cotton) or 12,359,600 t/year (fruit).

7.4.3 Calibration Factor

The calibration factor (which is in equation IV) increases the volume of water applied for production when the water price increases. The calibration factor was assumed to range between 0.00 and 0.1 in all markets, while keeping all other parameters constant. As illustrated in Figure A-3, the sensitivity analysis points out that rice production is affected most by a variation of the calibration factor while vegetable production is affected the least.

$\varepsilon \in \mathbb{Q} = \{0.00, 0.01, \dots, 0.1\}$ $\qquad$ $0.00 \geq \varepsilon \leq 0.1$

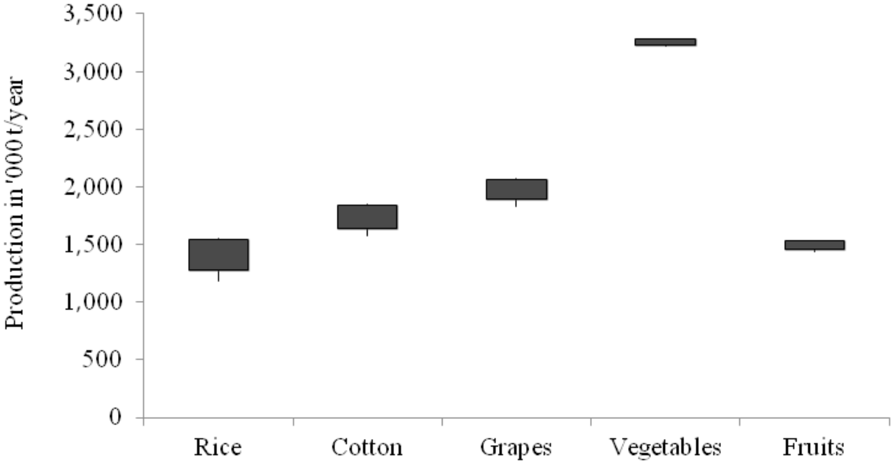

Figure A-3: Sensitivity analysis of the calibration factor

Table A-5: Sensitivity analysis of the calibration factor with higher and lower quartiles and extremes (in t/year)

Crop	Lower extreme	Lower quartile	Upper quartile	Upper extreme
Rice	1,183,833	1,273,233	1,541,433	1,556,333
Cotton	1,576,857	1,643,200	1,842,229	1,853,286
Grapes	1,832,000	1,889,600	2,062,400	2,072,000
Vegetables	3,214,333	3,231,133	3,281,533	3,284,333
Fruits	1,437,625	1,461,475	1,533,025	1,537,000

The calibration factor has an impact on crop production, particularly for rice and cotton. This can be due to the higher water consumption for crop production in these two markets than in the other markets. If the calibration factor is 0.00, crop production would be 1,556,333 t/year (rice) or 1,853,286 t/year (cotton). With a calibration factor of 0.1, the crop production would be 1,183,833 t/year (rice) or 1,576,857 t/year (cotton).

By this sensitivity analysis, it is proven that the saturation quantity and the gradient of the demand curve as well as the calibration factor have a significant impact on the model, and the production variable.

7.5 Data on the Water Costs and the Total Cash Costs

Table A-6: Data from ABARE

		Mean	**(Rse)**	**Mean**	**(Rse)**	**Mean**	**(Rse)**	**Mean**	**(Rse)**	**Mean**	**(Rse)**
year		**2006–07**		**2007–08**		**2008–09**		**2009–10**		**2010–11**	
Rice											
Population	no.	225		65		36		553		553	
Sample Contributing	no.	23		6		9		25		25	
Water costs	$	57856	(24)	21908	(78)	75196	(60)	52040	(14)	30882	(16)
Total cash costs	$	443025	(30)	714325	(65)	1002071	(26)	446385	(12)	467030	(12)
Water applied	ML	1149	(20)	838	(79)	1637	(32)	745	(11)	896	(15)
Cotton											
Population	no.	182		233		253		795		795	
Sample Contributing	no.	39		28		56		69		69	
Water costs	$	45641	(32)	31718	(26)	33931	(24)	29160	(21)	23800	(25)
Total cash costs	$	1281408	(22)	1258444	(13)	1527732	(9)	1443169	(10)	1581061	(11)
Water applied	ML	1460	(26)	1288	(19)	1426	(13)	1351	(14)	1423	(11)
Wine grapes											
Population	no.	2632		2381		2231		2037		2037	
Sample Contributing	no.	214		219		143		130		130	
Water costs	$	12734	(20)	36277	(12)	26274	(15)	19782	(20)	11123	(14)
Total cash costs	$	186644	(11)	214488	(12)	208908	(10)	258538	(9)	264891	(9)
Water applied	ML	148	(11)	126	(17)	161	(8)	202	(12)	150	(16)
Vegetables											
Population	no.	1179		1114		753		773		773	
Sample Contributing	no.	94		104		103		104		104	
Water costs	$	18258	(67)	17932	(21)	16224	(29)	13011	(21)	9435	(24)
Total cash costs	$	294095	(37)	491240	(16)	499325	(21)	556639	(13)	564218	(13)
Water applied	ML	157	(21)	225	(21)	233	(22)	291	(10)	268	(22)
Fruit											
Population	no.	5743		5418		5139		4732		4732	
Sample Contributing	no.	440		455		378		354		354	
Water costs	$	12622	(24)	30059	(13)	19805	(9)	15029	(11)	8814	(11)
Total cash costs	$	195530	(16)	276533	(9)	246643	(9)	303370	(12)	304007	(12)
Water applied	ML	128	(16)	137	(11)	147	(8)	203	(11)	164	(17)

Source: Data from ABARE, sent on request from Dale Ashton (Ashton, 2012).

This data represents “estimates […] based on a sample rather than a census” (Ashton, 2012). Dale Ashton did several farm surveys in the MDB.

7.6 Ratio of Percentage of Water Applied to the Percentage of GVIAP

Table A-7: Determination of the reduction factor

$q_{w\ avail\ diff} = 2{,}500\ GL/year$

DRY YEAR **When available water is less than 2,500,000 ML/year**	**Ratio of % Water applied to % of GVIAP**					
	Rice	**Cotton**	**Grapes**	**Vegetables**	**Fruits**	**sum**
Water applied 2007–08 (MDB) in ML	**26,664**	282,568	433,862	124,017	356,082	1,223,193
% of sum of water applied	2	23	35	10	29	
GVIAP 2007–08 (MDB) in million AU$	7	193	1,104	718	1,182	3,205
% of sum of GVIAP	0	6	34	22	37	
Water productivity (GVIAP/volume of water applied) in AU$/ML	263	683	2,545	5,790	3,319	
% Water applied/% GVIAP = Reduction factor (x_m)	9.56	3.83	1.03	0.45	0.79	15.66

WET YEAR **When available water exceeds 2,500,000 ML/year**	**Ratio of % Water applied to % of GVIAP**					
	Rice	**Cotton**	**Grapes**	**Vegetables**	**Fruits**	**sum**
Water applied 2009–10 (MDB) in ML	246,909	763,924	427,580	129,403	449,862	2,017,678
% of sum of water applied	12	38	21	6	22	
GVIAP 2009–10 (MDB) in million AU$	89	617	719	539	1,081	3,044
% of sum of GVIAP	3	20	24	18	35	
Water productivity (GVIAP/volume of water applied) in AU$/ML	360	808	1,682	4,165	2,403	
% Water applied/% GVIAP = Reduction factor (x_m)	4.18	1.87	0.90	0.36	0.63	7.94

Source: own illustration, data from (Australian Bureau of Statistics, 2011b; Australian Bureau of Statistics, 2010d)

The Australian Bureau of Statistics defines the GVIAP as follows:

> “Gross Value of Irrigated Agricultural Production (GVIAP) refers to the gross value of agricultural commodities that are produced with the assistance of irrigation. The gross value of agricultural commodities produced is the value placed on recorded production at the wholesale prices realised in the marketplace. […]
>
> Estimating the value that irrigation adds to agricultural production is difficult. This is because water used by crops and pastures comes from a variety of sources. In

particular, rainwater is usually a component of the water used by irrigated crops, and the timing and location of rainfalls affect the amount of irrigation water required. Other factors such as evaporation and soil moisture also affect irrigation water requirements. These factors contribute to regional and temporal variations in the use of water for irrigation. In addition, water is not the only input to agricultural production from irrigated land – land, fertiliser, labour, machinery and other inputs are also used. To separate the contribution that these factors make to total production is impossible with current data.

Bearing this in mind, the definition of GVIAP does not refer to the value that irrigation adds to production, or the 'net effect' that irrigation has on production (i. e. the value of a particular commodity that has been irrigated 'minus' the value of that commodity had it not been irrigated) – rather, it simply describes the gross value of agricultural commodities produced with the assistance of irrigation." (Australian Bureau of Statistics, 2008a, p. ix).

7.7 Calculation of Total Operating Costs

Table A-8: Determination of water suppliers' costs

	MDB			**State Water (New South Wales)**			
	in '000			**in '000**			
Year	Water use total (rice, cotton, grapes, veg., fruits) in ML/year	Total operating expenses for irrigation services (rice, cotton, grapes, veg., fruits)* in AU$/year	Expenses/water used in AU$/ML	Total operating expenses in AU$/year	Revenue total in AU$/year	Volume of water deliveries (all users) in GL/year	Expenses/water deliveries in AU$/ML
2004–05	3,423	52,128	15	50,377	51,260	3,308	15
2005–06	3,906	61,097	16	71,561	84,524	4,575	16
2006–07	2,134	58,632	27	60,443	72,536	2,200	27
2007–08	1,223	72,666	59	66,833	69,262	1,125	59
2008–09	1,830	89,106	49	70,410	72,456	1,446	49
2009–10	2,018	86,668	43	72,163	81,299	1,680	43
Averages	2,422	70,049	35	65,298	71,890	2,389	35

* Determined from "Water use total (rice, cotton, grapes, veg., fruits) MDB" multiplied by "Total operating expenses State Water" divided by "Volume of water deliveries (all users) State Water".

Sources: own illustration and calculation, data "Water use total (rice, cotton, grapes, veg., fruits, MDB" from (Australian Bureau of Statistics, 2008b) (Australian Bureau of Statistics, 2010d) (Australian Bureau of Statistics, 2011b) and data “Total operating expenses, State Water”, “Revenue total”, “Volume of water deliveries” from (State Water Corporation, 2005) (State Water Corporation, 2008) (State Water Corporation, 2012).

7.8 Data from the State Contingent MDB Model

Table A-9: CLD Data – wet year – gained from the state contingent MDB model

	Water Price (AU$)	**Rice (t)**	**Cotton (t)**	**Grapes (t)**	**Vegetables (t)**	**Fruit (t)**
Water Use (GL)	25	7,839	2,911	545	0	1,654
Water Use (GL)	50	7,839	2,911	545	0	1,654
Water Use (GL)	75	4,973	2,911	545	0	1,654
Water Use (GL)	100	4,396	2,911	545	0	1,654
Water Use (GL)	125	4,206	2,911	545	0	1,654
Water Use (GL)	150	0	2,911	828	0	1,194
Water Use (GL)	175	0	2,911	828	0	1,194
Water Use (GL)	200	0	2,067	828	0	1,194
Water Use (GL)	225	0	1,529	828	0	1,168
Water Use (GL)	250	0	1,384	828	0	1,168
Water Use (GL)	275	0	787	828	0	1,164
Water Use (GL)	300	0	787	828	0	931
Water Use (GL)	325	0	787	828	0	931
Water Use (GL)	350	0	787	828	0	900
Water Use (GL)	400	0	787	828	0	900
Water Use (GL)	450	0	787	828	0	900
Water Use (GL)	500	0	0	828	0	900
Water Use (GL)	600	0	0	828	0	676
Water Use (GL)	700	0	0	828	0	123
Water Use (GL)	800	0	0	494	0	123
Water Use (GL)	900	0	0	494	0	123
Water Use (GL)	1,000	0	0	0	0	123

Source: Data provided by David Adamson on request (Adamson, 2013).

Table A-10: SLD Data – wet year – gained from the state contingent MDB model

	Water Price (AU$)	Rice (t)	Cotton (t)	Grapes (t)	Vegetables (t)	Fruit (t)
Water Use (GL)	25	6,063	2,911	420	0	1,654
Water Use (GL)	50	6,063	2,911	420	0	1,654
Water Use (GL)	75	3,581	2,911	420	0	1,654
Water Use (GL)	100	3,071	2,911	420	0	1,654
Water Use (GL)	125	2,888	2,911	420	0	1,654
Water Use (GL)	150	0	2,911	702	0	1,194
Water Use (GL)	175	0	2,911	702	0	1,194
Water Use (GL)	200	0	2,067	702	0	1,194
Water Use (GL)	225	0	1,529	702	0	1,168
Water Use (GL)	250	0	1,384	702	0	1,168
Water Use (GL)	275	0	787	702	0	1,164
Water Use (GL)	300	0	787	702	0	931
Water Use (GL)	325	0	787	702	0	931
Water Use (GL)	350	0	787	702	0	900
Water Use (GL)	400	0	787	702	0	900
Water Use (GL)	450	0	787	702	0	900
Water Use (GL)	500	0	0	702	0	900
Water Use (GL)	600	0	0	702	0	676
Water Use (GL)	700	0	0	702	0	123
Water Use (GL)	800	0	0	368	0	123
Water Use (GL)	900	0	0	368	0	123
Water Use (GL)	1,000	0	0	0	0	123

Source: Data provided by David Adamson on request (Adamson, 2013).

7.9 Pictures of On-Farm Pools in the MDB

Figure A-4: On-farm pool

Figure A-5: Various on-farm pools

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By comparing different pricing and non-pricing water management policies with the help of the Water Integrated Market Model, it is found that the impact of water demand reducing policies is most severe on crops that need to be intensively irrigated and are at the same time less water productive.
A combination of increasingly frequent and severe droughts and the application of policies that decrease agricultural water demand, in the same region, will create a situation in which the highly water dependent crops rice and cotton cannot be cultivated at all.

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