

**EXAMINING THE IMPORTANCE OF SPATIAL INFLUENCES ON IRRIGATORS'
WATER TRADING BEHAVIOUR IN THE SOUTHERN MURRAY-DARLING
BASIN**

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List of Abbreviations

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
AIC	Akaike Information Criterion
ASC	Australian Soil Classification
ASDD	Australian Spatial Data Directory
ASGS	Australian Statistical Geography Standard
ASRIS	Australian Soil Resource Information System
ATO	Australian Taxation Office
AUD	Australian Dollar
AWAP	Australian Water Availability Project
BIC	Bayesian Information Criterion
BMP	Best Management Practices
BoM	Bureau of Meteorology
BSMS	Basin Salinity Management Strategy
CEWH	Commonwealth Environmental Water Holder
CIT	Central Irrigation Trust
COAG	Council of Australian Governments
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CVM	Contingent Valuation Method
DoEE	Department of the Environment and Energy
DSEWPaC	Department of Sustainability, Environment, Water, Population and Communities
EC ($\mu\text{S}/\text{cm}$)	Electrical Conductivity (microSiemens per centimetre)
ESLT	Environmentally Sustainable Level of Take
GCS-GDA-94	Geographic Coordinate Systems - Geocentric Datum of Australia - 1994
GDP	Gross Domestic Product
GIS	Geographic Information System
GL	Gigalitre (one thousand megalitres (ML); one billion litres). A gigalitre (GL) is equivalent to 810.71 acre feet.
GMID	Goulburn-Murray Irrigation district
GMW	Goulburn-Murray Water
G-NAF	Geocoded National Address File

GRP	Gross Regional Product
GVAP	Gross Value of Agricultural Production
GVIAP	Gross Value of Irrigated Agricultural Production
ha	Hectare
IIO	Irrigation Infrastructure Operator
km ²	Square kilometre
l	Litre
LGA	Local Government Area
ln	Natural Logarithm
LTAAY	Long term average annual yield factor
MDB	Murray-Darling Basin
MDBA	Murray-Darling Basin Authority
MDBC	Murray-Darling Basin Commission
MDBMC	Murray-Darling Basin Ministerial Council
MIA	Murrumbidgee Irrigation Area
MIL	Murray Irrigation Limited
ML	Megalitre (one million litres)
NA	Not applicable
NLWRA	National Land and Water Resources Audit
no.	Number
NRM	Natural Resource Management
NSW	New South Wales
NWC	National Water Commission
NWI	National Water Initiative
Obs.	Observations
OLS	Ordinary Least Square
PCA	Principal Component Analysis
pH	Potential of Hydrogen
PP	Primary Production
QLD	Queensland
RIT	Renmark Irrigation Trust
RMB	Roadside Mail Box
RSD	Roadside Delivery
SA	South Australia
SA1	Statistical Area Level 1

SA2	Statistical Area Level 2
SA4	Statistical Area Level 4
SDL	Sustainable Diversion Limit
SRWUI	Sustainable Rural Water Use and Irrigation Infrastructure
TDS	Total Dissolved Solids
TRA	Theory of Reasoned Action
TPB	Theory of Planned Behaviour
USA	United States of America
VIC	Victoria
VIF	Variance Inflation Factor
WAM	Water Audit Monitoring
WTA	Willingness to Accept
WTP	Willingness to Pay
\$m	Million Dollar

Glossary of Terms

Adaptation	The response to major changes in the environment (e.g. global warming) and/or political and economic shocks. Adaptation is often imposed on individuals and societies by external undesirable changes.
Adoption (in agriculture)	A change in practice or technology.
Annual crops	Crops that go through their entire lifecycle in one growing season (e.g. cotton, rice, cereal).
Basin Plan	A high level framework that sets standards (see sustainable diversion limits) for the management of the Murray-Darling Basin's water resources balancing social, environmental and economic outcomes.
Broadacre	Broadacre cropping (a term used mainly in Australia) describes large-scale agricultural production of grains, oilseeds and other crops (e.g. wheat, barley, sorghum).
Carry-over	Arrangements which allow water entitlement holders to hold water in storages (water allocations not taken in a water accounting period) so that it is available in subsequent years.
Catchment (river valley)	An area determined by topographic features, within which rainfall contributes to run-off at a particular point.
Commonwealth Environmental Water Holder (CEWH)	An independent statutory office established by the <i>Water Act 2007</i> and responsible for making decisions relating to the management of the Commonwealth environmental water aiming to maximise environmental outcomes across the Murray-Darling Basin.
Consumptive water use	The use of water for private benefit (e.g. irrigation, industry, urban, and stock and domestic uses).
Council of Australian Governments (COAG)	Is the peak intergovernmental forum driving and implementing reforms in Australia (members are the Prime Minister, State and Territory Premiers and Chief Ministers and the President of the Australian Local Government Association).
Environmental asset	According to the Basin Plan, include water-dependent ecosystems, ecosystem services and sites with ecological significance.
Environmental water	According to the Basin Plan, comprises water provided to wetlands, floodplains or rivers, to achieve a desired outcome, including benefits to ecosystem functions, biodiversity, water quality and water resource health.
Evapotranspiration	Sum of the moisture loss through evaporation and plant transpiration to the atmosphere.
Farming water season	Describes a 12-month period from July 1 to 30 June (similar to the financial year in Australia).
Geocoding	The process of assigning coordinates to address data by comparing the input address data to reference address data.
Groundwater	The supply of freshwater found beneath the earth's surface (typically in aquifers).

High security water entitlement	Provide a highly reliable water supply (usually full allocation 90-95 years out of 100) with not much variation between the years (except during extreme drought).
Irrigation Infrastructure Operators (IIO)	An entity that operates water service infrastructure to deliver water for the primary purpose of irrigation.
Long term average annual yield factor (LTAAY)	Expected long-term average annual yield from a water entitlement over a 100 year period.
Low/general security water entitlement	Provide a variable/uncertain water supply. General security provides LTAAY between 42-81%, and low security provides LTAAY between 24-35% in the Murray-Darling Basin.
Neighbourhood effect	The impact of neighbourhoods (neighbours' behaviour) on individual behaviour. Also referred to as spill-over effect.
National Water Initiative (NWI)	The national blueprint for water reform, agreed in 2004 by the Council of Australian Governments (COAG), to increase the efficiency of Australia's water use, leading to greater certainty for investment and productivity, for rural and urban communities and for the environment.
Over-allocation	The total volume of water able to be extracted by the holders of water (access) entitlements at a given time exceeds the environmentally sustainable level of take for a water resource.
Regulated river system	Rivers regulated by major water infrastructure, such as dams, to supply water for various uses.
Reliability	The frequency with which water allocated under a water (access) entitlement is able to be supplied in full.
Resilience	The ability of a system to return to its former state following a shock or disturbance. Resilience is a dynamic and systems orientated approach focusing on the adaptive capacity (i.e. the potential or ability of a system to adapt to cope with changes and uncertainties) as a fundamental feature of resilient systems.
Run-off	Excess water (e.g. from precipitation or irrigation) that flows to streams.
Permanent crops	Trees or shrubs, not grown in rotation, but occupying the soil and yielding harvests for several (usually more than five) consecutive years. Permanent crops mainly consist of fruit and berry trees, bushes, vines and olive trees and generally yield a higher added value per hectare than annual crops.
Salinity	The salt content in soil or water.
Spatial data	Can be imported into a geographic information system (GIS) and relates to space or a specific location and provide information about the locations and shapes of geographic features as well as the relationships between them. Spatial data is usually stored as coordinates and topology.
Spatial dependence	The tendency of the same variables measured in locations in close proximity to be related (i.e. similar values with similar locations). Spatial dependence may be caused by neighbours' interaction, measurement errors spilling across boundaries, or spatially correlated unobserved latent variables.
Stated preference	A survey-based technique for establishing valuations of people (sometimes referred to as contingent valuation), typically in the form of willingness to

	pay/accept (as compared to revealed preference, which focuses on the actual decisions made).
Structural adjustment	The ongoing process of change in the relative size, composition and characteristics of industries and their workforces across all sectors of a national or regional economy in response to a range of environmental and market factors, technological change and government policy reforms.
Surface water	Water that flows over land and in watercourses or artificial channels.
Sustainable diversion limit (SDL)	Maximum amount of water that can be taken for consumptive use reflecting an environmentally sustainable level of take (i.e. extractions must not compromise key environmental assets, ecosystem functions or productive base).
Transboundary water	A body of water that is shared by or forms the boundary between two or more political jurisdictions.
Unbundling	The legal separation of rights to land and rights to access water, have water delivered, use water on land or operate water infrastructure, all of which can be traded separately.
Unregulated river system	Rivers without major storages or rivers where the storages do not release water downstream.
<i>Water Act 2007</i>	An Act to make provision for the management of the water resources of the Murray-Darling Basin, and to make provision for other matters of national interest in relation to water and water information, and for related purposes.
Water allocation	A specific volume of water allocated to water (access) entitlements in a given season, according to the relevant water plan and the water availability in the water resource in that season (also known as temporary water).
Water buyback program	Principal government market-based instrument in Australia to produce environmental benefits in deteriorated sites across the Murray-Darling Basin by purchasing water entitlements from willing irrigators. In other words, water, previously allocated for consumptive uses, is reallocated back to the environment.
Water entitlement	A perpetual or ongoing entitlement to exclusive access to a share of water from a specified consumptive pool as defined in the relevant water plan (also known as permanent water).
<i>Water for the Future</i>	A 10-year initiative of the Australian government to better balance the water needs of communities, farmers and the environment and to prepare Australia for a future with less water. Initially, the budget was set at AUD\$12.9 billion, which allocated AUD\$3.1 billion towards a water buyback program and AUD\$5.8 billion towards Sustainable Rural Water Use and Irrigation Infrastructure (SRWUI) projects. Over the years, the budget was increased, primarily for the purpose of the infrastructure program.
Water recovery	Recovering water for the environment through investing in infrastructure to achieve greater efficiency and through the purchase of water entitlements.
Willingness to pay/accept	The acceptable bid amount that an individual is prepared to pay/receive for acquiring/giving up the good in question.

Abstract

Water trading is increasingly becoming an important farm management tool for irrigators to manage changing environmental conditions. Studies have found that water trading increases farmers' flexibility in water use and moves water from lower value (or less efficient) uses to higher value (or more efficient) uses. Many countries that regularly suffer periods of droughts and have over-allocated water resources face a growing challenge to allocate water to competing water uses. Some of these countries have introduced water markets as a response to help enable an efficient allocation of a scarce resource. This is especially so in Australia's Murray-Darling Basin (MDB), which has had water markets in place for decades. The southern MDB is one of the most active water trading region worldwide, and hence, provides an ideal case study for examining water trading behaviour. The MDB faced the Millennium Drought in the 2000s which caused intensive distress for all alike: irrigators, tourists, rural communities and especially the environment. During the midst of this drought the Federal government introduced a water buyback program that purchased water entitlements from willing irrigators to return to environmental use.

To date, a number of studies have investigated irrigators' determinants to trade water. This literature has primarily focused on farmers' socio-economic and farm specific characteristics. But there is evidence that water trading is also affected by spatial factors, especially water entitlement trading. Thus, this thesis explores the relevance of spatial influences on irrigators' water trade decision-making. Traditional economic models of water trading behaviour are expanded with several spatially explicit variables, such as biophysical and distance factors. The influence of neighbours' water trading decision-making ('neighbourhood effect') is also tested, as anecdotal evidence shows that in the past irrigators experienced considerable social pressure if they sold or were willing to sell water entitlements. Furthermore, this thesis also examines the influence of spatial factors on irrigators' price choices for selling and buying water entitlements.

The results show that a number of spatial influences significantly affect water trading behaviour, especially water entitlement selling behaviour. Irrigators located in poorer resource areas (e.g. regarding soil degradation), in more rural areas and regions that suffer a socio-economic decline (e.g. population decline) are more likely to sell water entitlements. There is evidence of a substitution effect between surface-water and groundwater (where viable groundwater resources exist). Irrigators in more rural areas tend to sell larger volumes of water entitlements and buy larger volumes of water allocations. Furthermore, a positive neighbourhood effect is confirmed, where irrigators' decisions to sell water entitlements was

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influenced by their neighbours. Over time, it became more socially acceptable to sell water entitlements. Finally, spatial influences also affect irrigators' valuation of their water, which is reflected in their price choices for water entitlement selling.

Overall, the results of this thesis support some existing policy measures and programs (e.g. salinity impact zones) and lead to several other policy implications. One such conclusion is the need to focus policy on water entitlement buybacks rather than on water irrigation infrastructure. This thesis concludes that current and future policies (e.g. related to the water buyback) could be more spatially targeted while also considering the externalities and wider irrigator behaviour in policy development. Spatially refined policies have the potential to improve the outcome of water markets (and related environmental programs) and alleviate the pressure on socio-economic and environmental systems.

Declaration

I certify that this work contains no material which has been accepted for the award of any other degree or diploma in my name, in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person, except where due reference has been made in the text. In addition, I certify that no part of this work will, in the future, be used in a submission in my name, for any other degree or diploma in any university or other tertiary institution without the prior approval of the University of Adelaide and where applicable, any partner institution responsible for the joint-award of this degree.

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Publications and Presentations from this Thesis

Journal article (peer-reviewed)

Haensch, J, Wheeler, SA, Zuo, A & Bjornlund, H 2016, 'The Impact of Water and Soil Salinity on Water Market Trading in the Southern Murray–Darling Basin', *Water Economics and Policy*, vol. 1, no. 4, p. 26.

Book chapter (peer-reviewed)

Haensch, J, Wheeler, SA & Zuo, A 2016, 'The contribution of spatial analysis to water management: a case study of the Murray-Darling Basin, Australia', *Advances in Environmental Research, Volume 51*, Nova Science Publishers, Inc., Hauppauge, NY, p. 18.

Conference paper (peer-reviewed)

Haensch, J, Wheeler, SA & Zuo, A 2017, 'The spatial distribution and determinants of stated price choices for water entitlement trading', Contributed paper, *61th Australian Agricultural and Resource Economics Society*, Brisbane, 8-10 February.

Haensch, J, Wheeler, SA & Zuo, A 2016, 'Location, Location, Location: the spatial influences on water entitlement selling in the southern Murray-Darling Basin', *45th Australian Conference of Economists 2016*, Adelaide, 11-13 July.

Haensch, J, Wheeler, SA & Zuo, A 2016, 'The spatial influence of neighbours' water sale behaviour on irrigators' water entitlement selling', Contributed paper, *60th Australian Agricultural and Resource Economics Society*, Canberra, 2-5 February.

Other conference paper/presentations (non peer-reviewed)

Haensch, J, Wheeler, SA, Zuo, A & Bjornlund, H 2016, 'The Impact of Water and Soil Salinity on Water Market Trading in the Southern Murray–Darling Basin', *Climate Adaptation 2016 Conference*, Adelaide, 6 July.

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