Modelling the implications of water reform on sugar cane farms in the Lower Burdekin region

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Abstract: Water reform is a national priority in Australia. The Council of Australian Governments (COAG) put a framework for water reform in place in 1994, which imposes on irrigation regions stringent pricing requirements for water and the inclusion of environmental considerations into allocation decisions. Many irrigation areas do not yet comply with COAG requirements. The Lower Burdekin in north-east Queensland is one of these irrigation areas. This paper reports on the development of a modelling framework to investigate the impacts of potential water reform scenarios for the Lower Burdekin. The first part of this paper reports on the application of soft systems methodology to develop a conceptual model of (1) the implications of water reform for irrigators and (2) regional-scale flow-on effects. The second part of the paper outlines the development of a quantitative model of water reform to proof-of-concept stage. Initial analysis of potential water reform scenarios are presented and discussed in terms of trade-offs between economic, social and environmental objectives.

Keywords: *Water reform; Sugar industry; Water trade; Applied General Equilibrium Modelling; Lower Burdekin*

1. INTRODUCTION

Sugar production constitutes the vast majority of agricultural production in the Lower Burdekin irrigation area in north-east Queensland. The Lower Burdekin includes the delta of the Burdekin River and the adjacent Houghton river flood plains. Irrigation water comes from two sources: groundwater is extracted from the unconfined groundwater systems and surface water comes as diversions from the Burdekin River, which is dammed about 100 kilometers upstream.

Increasing demands arise for changes to irrigation management in the Lower Burdekin, as in other irrigation areas, from environmental considerations and the national policy context.

Firstly, water management in the Lower Burdekin at present does not meet Council of Australian Government (COAG) requirements (AFFA, 2002). The COAG developed a national policy for the efficient and sustainable reform of Australia's rural and urban water industries in 1994, called the water reform framework. This framework requires, *inter alia*, that all water pricing is to be based on the principles of full cost recovery and transparency of cross-subsidies and that any new investment in irrigation schemes, or extensions to existing schemes, are to be undertaken only after appraisal indicates it is economically viable and ecologically sustainable. All irrigation areas in Australia must comply with COAG requirements by the year 2005.

Secondly, altered flow regimes in the Burdekin River and runoff from agricultural land have been linked to water quality problems and associated risks of detrimental effects to biodiversity in-stream as well as in adjacent estuarine, coastal and marine ecosystems, specifically the Great Barrier Reef. Proposed water quality targets demand a reduction in sediment and nitrogen export of the Burdekin river of 50% and of phosphorus of 33% by the year 2011 (GBRMPA, 2001)

Thirdly, irrigation is associated with salinisation problems that threaten the productivity of land and water resources. Specifically, two types of salinisation impact on the Lower Burdekin. There is increasing concern about the potential for seawater intrusion and subsequent salinisation of groundwater systems. Irrigation salinity is starting to appear in parts of the lower Burdekin, as a result of rising groundwater tables.

There is great concern among the irrigation industry that changes to water management will cause significant losses in profitability and employment. It is the objective of the research reported here to provide an understanding and analysis of potential consequences for the sugar industry in the Lower Burdekin of various options for water reform.

This paper reports in Section 2 on the overarching participatory action framework in which the work is embedded. Section 3 outlines a quantitative modelling approach and how this approach has been progressed to proof-of-concept stage.

Section 4 shows model results based on selected scenarios of potential water reform. This is followed by a discussion of methodology and results in section 5.

2. PARTICIPATORY ACTION RESEARCH

The primary purpose of the research is to provide a clearer understanding of possible implications of water reform for the sugar industry in the Lower Burdekin. The purpose of this understanding is to inform the water resources planning process in the Burdekin catchment and contribute to the design of policies for water reform.

A collaborative approach is essential since regional communities now see themselves as stakeholders and demand firstly, more involvement in the decision-making processes affecting their regions and secondly, accountability for activities that impact on the environment (Smith and Mcdonough, 2001). A collaborative process with the sugar industry and its stakeholders has been undertaken to derive a common understanding of the issues associated with water management and the economic, social and environmental flow-on effects.

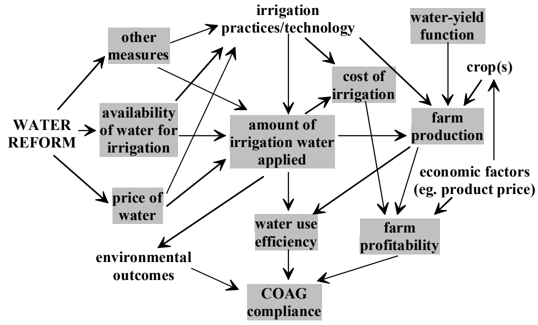
Participation of key stakeholder groups in collaborative processes is essential in the sugar industry to improve (Walker et al., 2002):

1. Planning capacity within stakeholder groups;
2. Interaction among government, sugar industry and community;
3. Negotiation processes through the development and implementation of participatory planning methodologies.

In addition to regular stakeholder briefings and review of the research, a workshop was convened, which provided an important avenue for a wider set of stakeholders to provide input into the development of an initial conceptual framework of water management (Figure 1). This framework is to be refined based on previous research in the region and additional stakeholder input.

At a conceptual level, this model can help to explore some of the complexities of the system under investigation. However, a numerical approach is required to test water reform scenarios for the (a) magnitude of production and on-farm impacts and (b) compliance with COAG principles. The remainder of this paper introduces a regional scale economic model to explore the impact to sugar production and other economic imperatives in relation to water reform scenarios.

Figure 1 Conceptual model of water reform and impact



3. A NUMERICAL MODEL OF WATER REFORM

Changes to water management will have impacts at the regional scale but also at the farm scale. Those impacts are likely to differ between different types of farm, depending on their water source and geographical location.

3.1. Problem formulation

The bio-physical system

Water use in the Lower Burdekin irrigation area is conjunctive, meaning that farmers use either surface water or groundwater, or both for irrigation.

Three water management bodies operate within the Lower Burdekin irrigation area, with significant differences in water management (Figure 2). The North and Southern Burdekin Water Board (NBWB and SBWB) areas cover the northern and southern parts of the Burdekin river delta, respectively. There is as yet little regulation of the use of irrigation water and charges for water are on an extraction-cost basis. Irrigators extract predominantly groundwater but surface water is also applied generously to replenish groundwater aquifers. Water use is not metered. Management of the groundwater system is the key objective of the water boards to prevent seawater incursion in coastal areas but also the development of irrigation salinity.

In contrast, water use in the Burdekin Houghton Water Supply Scheme (BHWSS) is more tightly regulated and priced. Surface water use is capped at 8 megalitres per hectare for each year and it is priced at $30 per megalitre. Most water use is from surface water. SUNWATER, the water provider, pursue commercial objectives in running its operation.

Figure 2: Water management areas within the Lower Burdekin irrigation area

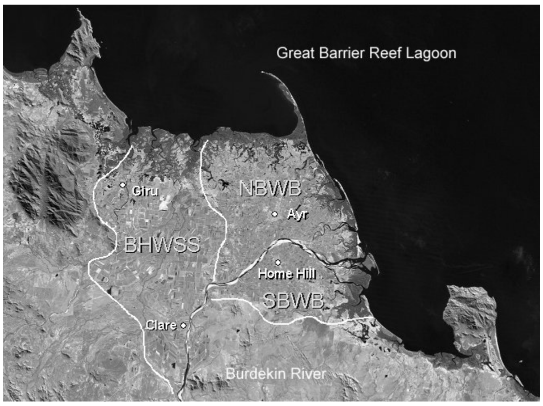


Table 1: Dimensions for design of water trading scheme

Dimension	Options		
Type of cap	absolute number	specific (benchmark point)	specific (benchmark range)
Cap differentiation	water	2 caps: SW and GW	optimal GW table
Allocation quantity	current water use	determined year	benchmark
Allocation price	“grandfathering”	fixed price	auction
Participation	forced		voluntary
Participation deduced from	production		consumption

GW: groundwater; SW: surface water

The economic/policy system

Water reform can be implemented through a series of policy instruments (see figure 1), applied in isolation or combination. Principally these are quantities and price-based mechanisms, and combinations thereof. It is important to identify the full suite of design possibilities and enable a comparison of different options.

Experience from other irrigation areas in Australia shows that the three instruments, per-hectare allocations (caps), mark-ups per unit of water and water trading schemes, are commonly applied policies (ANCID, 2001). Water trading, in particular, is a way of maximizing efficiency of water use as water rights are sold by low-efficiency farms and purchased by high-productivity enterprises.

Water trade schemes can also be called ‘cap-and-trade systems’. It is necessary to define a cap of total use in a system, to define property rights on the individual use, and to allow the trade of these permits within the system.

Major dimensions in the design of a water trade scheme are the type of cap, the cap differentiation, the allocation system, the allocation price, and the definition of participants. Table 1 provides an overview of options.

A necessary condition for the introduction of all policies is that water use, both from surface and groundwater, is being metered. This condition is not presently fulfilled in the Lower Burdekin.

A single cap on water use has an impact on surface water (SW) and ground water (GW). The differentiation of caps for surface and ground water is likely to lead to different price levels for the two water types, depending on the access of farmers to the two water types and on their pump costs.

Allocation focuses on the way to spread the permits. This aspect requires a distinction between initial allocation and ongoing allocation. The initial allocation is part of the policy decision and defines the amount of permits each irrigator gets at the time when the water trading scheme is introduced. Ongoing allocation outcomes result from individual decisions to sell or purchase water rights.

There are different ways of defining initial allocation. One possibility is to take the past water use as the reference point for allocation. Another approach is to derive the amount of allocated permits from a defined benchmark, for example on a megalitre-per-hectare basis. The initial allocation can be free of charge (‘grandfathering) or sold for a fixed price, or it can be sold at auction.

Participation in a water market can be defined on a geographical or sectoral basis. Participation can be compulsory or voluntary.

3.2. Methodology

Choice of methodology is governed by the research question. The question pursued here is what would be the likely impacts of various options of implementing water reform on irrigation farmers.

Questions of resource allocation are best analysed by optimisation models or Applied General Equilibrium (AGE) models.

Optimisation models maximize a utility function, subject to a series of constraints. The result shows optimal behaviour of agents. In the natural resources field, optimization is frequently applied to show, for example, the optimal extraction path of non-renewable resources or optimal land use systems and water application (McKinney and Cay, 2002).

AGE models analyse problems from a policy perspective. They assume optimal behaviour of agents. The purpose is to predict impacts of policy decisions at a regional or national scale. AGE models assume equilibrium for one period. Scenarios are designed to define a benchmark and a set of changed circumstances. Results show how agents would behave under alternative conditions (Ginsbergh and Keyser, 1997).

An AGE approach is therefore ideally suited for the investigation of regional-scale impacts of water management systems. Model results can identify the effects on production, water use and water price, as well as 'winners' and 'losers' in relation to the benchmark.

4. WATER TRADE MODEL "WATER AGE"

This section describes development of an AGE model for the question at hand. The model is a proof-of-concept model translating the conceptual model of figure 1 into a numerical model, based on an artificial data set. The artificial data are designed to resemble the conditions in the Lower Burdekin. It is intended to gather data that will enable customization of the model for the Lower Burdekin.

4.1. Model features

The AGE model, called "WATER AGE" is a one-sector model, where production (Y) is dependent on the input of three production factors, capital (C), labour (L), and water (W). The production functions are nested and allow some degree of substitution between the production factors.

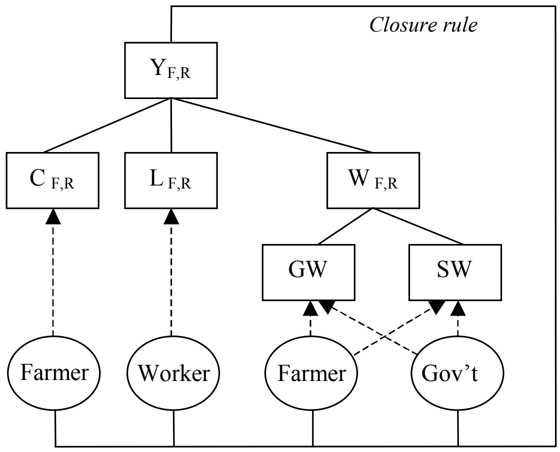
The model specifies three actors (farmers, workers, and government). The current model is one-sectoral (sugar cane), where the utility function is defined in terms of sugar production, meaning sugar is the currency of demand and supply exchange between actors. Capital is provided by farmers and labour by workers. This simplification helps to focus the model on the main drivers to predict the effect of a new water management system.

Irrigation water comes either from groundwater (GW) and/or surface water (SW). Ground and surface water have to be pumped, involving pumping costs. Farmers also pay a volumetric charge to the government (gov't) for the use of ground and surface water.

Figure 3 displays the structure of WATER AGE.

There are three different farm types (F), one with access to both ground and surface water (GSW) one with access to surface water only (OSW), and one with access to ground water only (OGW).

Figure 3: Model structure of WATER AGE



Three different regions are considered, resembling broadly the BHWSS, NBWB, and SBWB areas in the Lower Burdekin. This framework leads to a matrix of nine different types of sugar cane farms, differentiated by location and water access. This definition does imply that all nine combinations exist.

4.2. Scenario definition

The water trading scheme is defined by absolute caps for every irrigator (shaded cells in Table 1). Two different caps are set up, one for surface water (SW) and one for ground water (GW). The quantity taken for the initial allocation is the estimated current water consumption. Irrigators incur no cost for initial allocation (grandfathering). Participation in water trade is compulsory.

The quantity taken for the initial allocation is based on estimated current use of irrigation water. The benchmark assumes different access to ground and surface water for the different farm types and different fees for the use of ground and surface water depending on geographical location. Farmers in R1 pay four times as much for water as farmers in the R2, and farmers in R3 pay 2.5 times as farmers in R2. The relativity of those numbers will allow a representative forecast of the impact of a potential water reform on the different types of farms in different regions. Comparisons of results between benchmark and scenario identify winners and losers for different policy options, helping to elicit the best water reform design.

Scenario 1 defines a cap on surface water, as the current debate seems to focus on this issue more than on the interplay of surface and groundwater.

Surface water availability is reduced by 10% for region 1 while the two other regions (with higher current water use) face a reduction of 30%. At the same time the irrigators are allowed to pump 10% more ground water to allow substitution of water sources for those farmers with access to both surface and groundwater.

Table 2: Benchmark and scenario definition

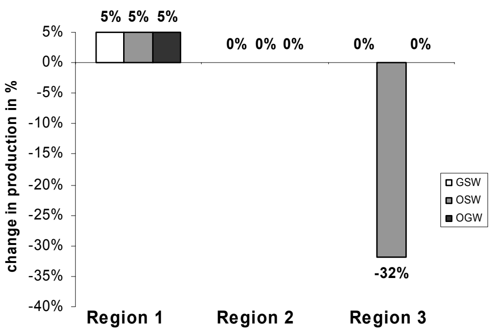
Assumptions	Bench-mark	Scenario 1	Scenario 2
Surface water cap	no	yes	yes
Groundwater cap	no	no	yes
Water trade	no	yes	yes

Scenario 2 analyses the effect of an additional cap on ground water extraction. This is important as both, reduced surface water application and increased groundwater extraction lead to a decline in groundwater table and potential salinisation. The cap on ground water is based on the benchmark extraction and is assumed to be 0% for region 1, 15% for the region 2, and 20% for region 3.

5. Results and interpretation

The effects of a cap-and-trade concept on sugar cane production vary substantially between farms (Figure 4).

Figure 4: Production impact in scenario 1



Farms with current higher water-use efficiency (region 1) would gain by increasing production. In contrast, specifically farms that are reliant on surface water only in areas with low water-use efficiency (region 3) are affected negatively. Their production drops by 32% because they rely most on that factor price increases most in a relative view. This effect is heightened in scenario 2, where sugar production on surface-water-only farms in region 3 declines by 60%.

However, the sale of water entitlements provides a new source of income for farmers so the income impacts are quite different from the production impacts. Figure 5 shows for scenario 1 that irrigators who rely solely on groundwater have relative advantages and those irrigators who rely entirely on surface water and are currently least efficient have most to loose. However, as soon as groundwater use is capped as well (scenario 2), all types of farm show clear welfare or income losses, with surface-water-only irrigators being the worst off.

Figure 5: Farmers' welfare impact in scenario 1

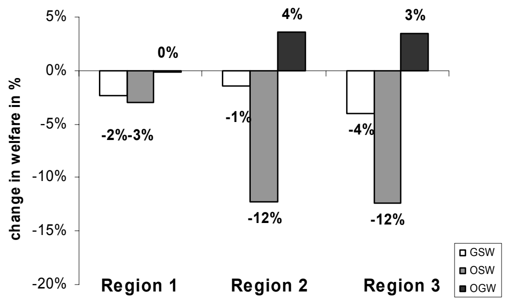


Figure 6 shows the amounts of water permits traded. The income from this new source is included in the welfare effects shown in Figure 5. While region 1 as the currently most efficient one is able to sell permits, the farms using surface water have to buy permits in scenario 1.

Figure 6: Water trade in scenario 1

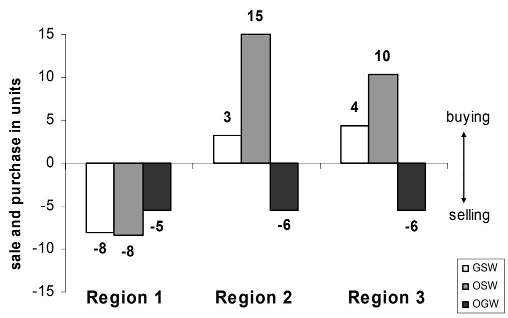
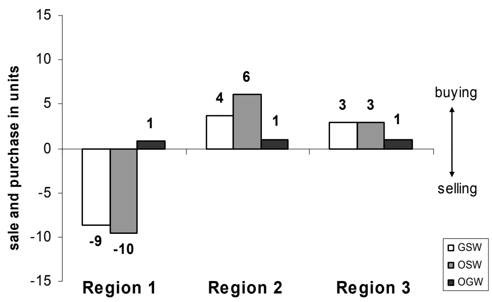


Figure 7: Water trade in scenario 2

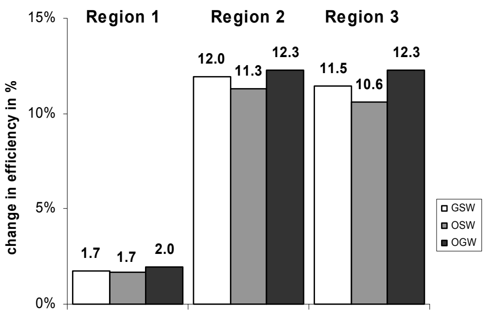


The additional cap on ground water changes the situation significantly, as shown in Figure 7. In this scenario, all farm types in the less efficient regions have to buy permits. This also explains the change in welfare. Farms using surface water in the efficient region 1 gain for the change in relative prices between ground and surface water.

As a key driver for water-use management it is essential to analyse the effects on water-use efficiency.

A cap on surface water-use leads to a slight improvement of efficiency of between 3% and 3.5% in the less efficient regions. Figure 8 shows that the additional cap on ground water achieves significant efficiency improvements of between 10.6% and 12.3% because irrigators do not have the possibility to switch to a free good (groundwater in scenario 1). In scenario 2 the options are to either improve efficiency and/or reduce production.

Figure 8: Water-use efficiency in scenario 2



6. Conclusions

This paper describes the development of a framework to investigate the impacts of potential options for water reform in the Lower Burdekin irrigation area. A proof-of-concept numerical model, based on applied general equilibrium methodology is developed from the conceptual framework displayed in Figure 1. Results of initial scenarios are shown.

The simple model clearly identifies the types of impacts that different ways of implementing water reform could be expected to exert on irrigators. The impact of a simple cap-and-trade system can vary significantly depending on the locations and types of irrigation operations. The size of impact differs significantly for different ways of implementing water reform.

Size and distribution of impacts varies significantly depending on how water reform is implemented. Given the abstract character of the model, these results have to be interpreted as an orientation guide for likely interplays.

In addition to customizing the model for the Lower Burdekin irrigation area, the model would benefit from a series of improvements. The model has, at current, no environmental dimension (see shaded fields in Figure 1). It would be useful to capture the effects of irrigation on the groundwater table, given that the groundwater table is critical for controlling salinisation.

Another aspect of improvement is to consider different sectors. This would show, for instance, the effect on sugar mills and other agricultural products competing for the labour or land. A further step would be to consider other regions important to sugar cane production worldwide. As sugar cane is a homogeneous good competitiveness has to be seen in a global context.

This concludes a major goal of this project to find that specific concept which collateralises the environmental standard by minimising the economic effects.

7. Acknowledgements

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