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The Basin Plan, the Buy-Back and Climate Change: Determining an Optimal Water Entitlements Portfolio

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The long-term success of the Basin Plan and the Buy-Back will be judged by the capacity of the allocated public funding to deliver water to the environment, potable water supplies for the community and water for irrigation. Water property rights in the Murray-Darling Basin can be divided into four distinct groups (ground water, high security, general security and supplementary) reflecting their inherent capacity to deliver water supplies in response to climatic conditions in a given year. The price paid for these entitlements reflects their ability to provide water under known climate variability. The optimal portfolio of water entitlements needs to encapsulate this information in order to determine which entitlements to purchase, the number needed and their location in the river system in order to deliver net social benefits.

The optimal portfolio of entitlements is further complicated by the climate transitioning from a known mean and variance to a new mean and variance. The spatial impact of climate change on water resources is not uniform. Hence what is seen as a good portfolio now may in fact be sub-optimal in the future.

The aim of this paper is to illustrate the benefits of a state contingent framework for describing the optimal portfolio of water entitlements under a changing climate. By explicitly determining the real value of water entitlements in normal, drought and wet states of nature, we can determine the Buy-Back's ability to achieve the Basin Plan's goals and suggest an optimal entitlement mix to deliver long-term economic, social and environmental benefits under climate change.

1. INTRODUCTION

The Basin Plan is designed to restore the balance between all water users (environment, irrigators and urban) in Australia's Murray-Darling Basin (Basin). By determining a sustainable diversion limits (SDL) for the Basin negative externalities associated with over-allocation of water resources to irrigation are then mitigated. Negative externalities include environmental harm and dissolved salts in the water impacting all water users. Water resources in the Basin are described as the second most variable in the world (Khan 2008). Consequently irrigation water property rights have been developed to represent this uncertainty in water supply (i.e. normal, droughts and floods). Water property rights can be classified within four groups which have a declining reliability of supply: ground water, high security water, general security water and supplementary entitlements. The unique nature of catchment inflows then determines the reliability of each entitlement and ultimately determines their value to irrigators.

Under the Basin Plan the cost of transferring water resources from irrigators to other users occurs at the public expense. In this paper we only examine the ability to reallocate water resources between all users by purchasing water entitlements from irrigators (Buy-Back). Thus with a defined public budget the question for the government then becomes: "what is the optimal bundle of goods to purchase in order to achieve the adjustment for maximum net social benefit?" Social benefits in this paper are determined by irrigation economic activity, minimizing salinity levels and achieving minimum standards for environmental flows. If social benefits to the environment and salinity targets are specified by climatic variability (or climate states of nature) then the entitlements purchased, must be able to secure water supply by state of nature within the budgetary expense. Complication to the problem is added by the introduction of climate change. As the spatial change to the known mean and variance of future water supply is not uniform, what is seen as a good portfolio of rights to purchase now may be sub-optimal in the future. The objective of this paper is to examine the role of climate change in determining an optimal bundle of water entitlements to achieve the Basin Plan's objectives.

This paper does not model the changes to water that could occur under the $5.8 Billion capital works program for three key reasons. Firstly as the Arup (2011) points out it is at least 3 times more expensive to return water for the environment via the irrigation modernization program versus the Buy-Back. Secondly historically engineering solutions to improve environmental quality in the Basin, for example salinity mitigation, face steep increases in costs once the initial low cost gains have been made (Schrobback, Adamson and Quiggin 2008). These first two factors then suggest that the Buy-Back will return more water to the system than the irrigation modernization program. Thirdly, increasing water efficiency may promote inflexible production systems causing long run problems.

To achieve these goals this paper has been divided into the following sections. First a discussion to why the Basin Plan was developed is provided. Secondly a rational as to why explicitly modeling conjunctive water resources and environmental targets under climate variability and climate change is important is presented. Thirdly the way the state contingent model described in Adamson, Quiggin and Quiggin (2011) was adapted to this problem is outlined. A series of findings regarding the future of water resources and the possible Basin Plan outcomes are then detailed before final comments are made.

2. WHY IS A PLAN NEEDED FOR THE MURRAY-DARLING BASIN

The Basin is of national importance in Australia due to its size, environmental assets, and economic activity. Approximately 14% Australia lies within the Basin borders and 80% of the Basin is dedicated to agriculture. The Basin produces about 40% of Australia's gross value of agricultural production of which one third of the value of the Basin agricultural output is derived from irrigation activities. Within the Basin's borders there is an estimated 440,000Km of river systems feeding over 30,000 wetlands scattered over 25,000 Km2. Over 10% of Australia's population lives in the Basin and a further 5% in Adelaide are dependent on the river systems delivering potable drinking supplies (Adamson, Quiggin & Quiggin 2011).

The total average conjunctive water resource in the Basin is estimated to be 26,500 GL comprised of 2,300 GL of ground water, 1,200 GL of transfers into the Basin from the Snowy River and the remaining inflows from rainfall runoff. The estimated current diversion limits (CDL) utilize 48% of the total water resources. As the Basin is regarded as having the second most variable runoff inflows in the world, the use of averages is misleading (Khan 2008). The natural flows within the Basin are subject to long periods of below average flow offset with large inundations. The spatial patterns of rainfall within the Basin are summer dominate in the north and winter dominate inflows in the south. Water supply in the southern Basin is generally considered to be more reliable than the north due to large scale capital infrastructure works (i.e. dams and water transfers from the Snowy River). This perception of reliability in the southern Basin was tested and found wanting during the recent drought (The Productivity Commission 2009).

Historically, two management approaches for dealing with water supply variability have been adopted. First a short run response of penalizing environmental supply to maintain irrigator supplies is adopted, with the goal that sequential time periods compensates environmental flows. Second, announcements concerning the percentage of allocation to be delivered to irrigators, subject to the description of the entitlements risk, are made throughout the year.

The recent decade long drought finished late 2010. During the initial drought phase the above management strategies were adopted but after multiple successive years of low inflows past known parameters, management changes occurred. For example, by 2005-06 high security licenses in the Goulburn region fell to only 30 per cent of their face value (NWC 2011). The reduction in water supply not only caused a short run price response on the allocation market in 2007-08 but ultimately forced significant changes in production and management responses in the subsequent season (Mallawaarachchi & Foster 2009). By 2008-09 Basin wide irrigation diversions were 4,100 GL, approximately one–third of diversions in 2001-02 (MDBA 2010). By late 2009, arguably for the first time ever, iconic environmental assets received water before irrigators to prevent total ecosystem collapse (SEWPaC 2011). This drought has forced the re-examination of the sustainable level of diversions in the Basin via the 2007 Water Act.

2.1. Water Resources, Climate Variability vs Change and Basin Plan Objectives

Water resources in the Murray-Darling Basin have been over-allocated to irrigators causing a series of negative externalities degrading both private and public goods and services. If irrigation production systems and river management strategies are tuned to only average water availability, then under drought periods water resource scarcity then causes significant economic loss via irrigation capital exposure, environmental degradation and reduction in quality for potable water supplies. These problems are exasperated under climate change as both mean and variance of water supplies alters Adamson, Mallawaarachchi & Quiggin (2009). Thus any attempts to develop sustainable diversion limits within the Basin must consider both the variability of supplies under the current climate and the variability of water supplies under climate change.

Both the environment and irrigators have adapted to the natural cycles of droughts and floods. Irrigators adapt by changing not only the output (commodity produced) but how they allocate inputs. For example, dairy producers sold water and purchased fodder (Ashton & Oliver 2011). While the environment evolved to these natural patterns and has adapted taking advantage of existing production systems (McIntyre *et al.* 2011). However, as water resources are both limited and over allocated to irrigators, in times of scarcity exceeding known variances in water supply (i.e. the severity and longevity of the recent drought) systems that are inflexible (perennial horticulture) fail to cope adequately in the short term. This is the issue with climate change. If the new mean and variance of inflow patterns alter then in the long-run management systems have to adapt or a reallocation of resources occurs. In this paper we keep the environmental objectives the same and examine how resources could be reallocated.

2.1.1. Climate Change

Australia's policy settings for climate change mitigation are derived from the Garnaut Climate Change Review. During that process a number of alternative climate change scenarios were developed and the impacts on water resources in the Murray Darling Basin are described in Quiggin *et al.* (2008). From that study the following three climate change scenarios are examined over two time periods (2050 and 2100).

The first scenario is that described as the best Estimate (median) strong mitigation scenario where stabilization of 450 ppm CO2 equivalent (CO2 stabilized at 420 ppm) is reached by 2100, 50th percentile rainfall and relative humidity surface for Australia, 50th percentile temperature surface. Mean global warming reaches ~1.5°C in 2100. Hereafter referred to as Climate 450 Avg (2050 or 2100).

The second scenario is the best Estimate (median) mitigation scenario where stabilization of 550 ppm CO2 equivalent (CO2 stabilized at 500 ppm) is reached by 2100, 50th percentile rainfall and relative humidity surface for Australia, 50th percentile temperature surface. Mean global warming reaches ~2.0°C in 2100. Hereafter referred to as Climate 550 Avg (2050 or 2100).

The third scenario is a dry mitigation scenario where stabilization of 550 ppm CO2 equivalent (CO2 stabilized at 500 ppm) is reached by 2100, 10th percentile rainfall and relative humidity surface for Australia (dry extreme), 90th percentile temperature surface. Mean global warming reaches ~2.0°C in 2100. Hereafter referred to as Climate 550 Dry (2050 or 2100).

This paper does not consider a scenario where the climate becomes wetter as simply under that scenario the problems associated with over-allocation are mitigated by nature. Rather this paper is testing what may happen when resource scarcity occurs compared to the current climate. If then Basin Plan is designed to achieve a rebalance for net social benefits, we need to know the objectives.

2.1.2. Bain Plan

For natural resource policy programs to succeed they must have clear goals. As Rostow (1959) explains that until the political and social objectives are set, that understand how the law of diminishing marginal return applies equally to natural resources, demand elasticizes and production function discontinuities, then economic growth is slowed. In the case of water...

> "An integrated analysis that makes environmental considerations explicit, could estimate the benefits of alternative environmental allocations and determine the optimal trade-offs between consumptive and non-consumptive uses of water. It could thus highlight potential synergies and opportunities to maximise social returns from the government investment."(Mallawaarachchi et al. 2010)

Therefore any evaluation of the long term success of the Basin Plan must have defined environmental and social targets that specify improvements by climatic states and by climate change. This paper helps the policy discussion as no economic review concerning climate change and the Basin Plan was commissioned during its last incarnation. During a review of one Basin Plan proposal, the environmental and social targets were defined as a minimum flow of 1,000 GL arriving at the Coorong and the maximum salinity in water arriving to Adelaide as 800 EC (Adamson, Quiggin & Quiggin 2011).

To achieve these targets water needs to be purchased from willing sellers. As the actual volume of water delivered to rectify any specific environmental asset or other externality along the Murray-Darling Basin in a given year is dependent on the mixed bundle of entitlements purchased and climatic conditions. Therefore we need to know the costs of purchasing water entitlements from irrigators, the amount of water each entitlement will deliver by climatic state, the number of entitlements in the Basin and the Basin Plans recommendation of SDL. The Basin Plan delivers a net contraction of 947 GL of the Basin's conjunctive water resources. This is achieved by ground water extractions increasing by 1,798 GL and a decrease of surface diversions by 2,745 GL. Of the surface reductions 1,631 GL has identified by specific catchment with a further 143 GL and 971 GL is expected to come within the Northern and Southern water trading zones respectively (MDBA 2011).

The Bureau of Meteorology (2011) provided the data for entitlements by catchment in the Basin. There are an estimated 3,582 GL of high security entitlements, 7,230 GL of general entitlements and 6,081 GL of supplementary entitlements. Data concerning the purchase of water entitlements by catchment was sourced from the programs web site. This data was also used to illustrate the opportunity cost to an irrigator from either using their water entitlements or selling them for environmental flows. This was achieved by transforming the data into an annuity which then allowed water sales to be modeled as a production choice. From this same data estimations of the reliability of flow for each entitlement was created for surface entitlements by climate state of nature (i.e. normal, drought and wet). In this paper ground water extractions are assumed to be guaranteed (i.e. no variability by state of nature),

The Buy-Back strategy has $3.1 billion set aside to purchase water from willing sellers. From the data provided this budget then has to purchase back 2,750 GL of surface water. For simplicity it has been assumed that all ground water will eventually go to irrigated agriculture. The cost of purchasing ground water has been set to zero for this exercise. This decision has been made as it is likely that this increased ground water extraction may in part be due to coal seam gas. As water is a by-product of the gas extraction system (Johnston & Ganjegunte 2008), it has been assumed that all the water is used for irrigation.

3. THE MODEL

Decision making in agriculture must incorporate uncertainty. Uncertainty abounds in agriculture since decisions and their outcomes are ultimately influenced by both external and internal variables. There are two main approaches for dealing with uncertainty in economics. The first has been to adopt stochastic production functions to describe the result of a decision but this approach fails to differentiate between production and management inefficiency on the outcome (O'Donnell & Griffiths 2006). This approach implies that decision makers remain passive in their management to outside information. In practical modeling terms this means a drought is represented by only a decrease in income either due to the function describing yield (e.g. as water use falls, output falls) and/or changes in price.

Chambers & Quiggin (2007) challenged this approach by suggesting that uncertainty could be represented by a set of states of nature. In other words, every possible outcome can be described within a state of nature (e.g. climatic event). Within each state of nature, irrigators actively respond by changing the inputs they use (e.g. water and labor), the product they produce (i.e. whether to stop irrigation and produce a dryland crop) and the technology used to produce output. This allows for production to be described with multi-output technology within a state space. A producer's response to each state of nature (e.g. drought) is based on their knowledge about that state of nature and past experiences of outcomes from state based decisions (i.e. changes in inputs and outputs). Current state decisions are then made on that knowledge and they respond by altering inputs to influence the final output in order to meet their objective function. This allows the state contingent approach to examine production outcomes and a decision maker's ability as separate entities. In practical modeling terms this means that a producer's response to a drought can be represented by not only changing the commodity produced (i.e. switch from irrigated to dryland commodity) but the inputs used to produce that commodity alter. As the state contingent approach also allows for the description of both social and environmental objectives to be specified by climate state it then helps determine the feasibility of the Basin Plan.

The model adapts work undertaken in Adamson, Oss-Emer & Quiggin (2011) on modeling the Buy-Back. For this paper, the model now separates ground water and surface diversions to illustrate climatic impacts on these alternative water resources to examine the Buy-Back and the 2011 Basin Plan objectives. This involved the separation of production systems into those dependent on ground water versus those dependent on surface water. The new model is described in Adamson (2012).

4. RESULTS

Chart 1 illustrates what may occur to water flow if the Buy-Back is optimized to purchase a bundle of entitlements to achieve the SDL under the current climate. In this case the benefits of water flowing in drought states to the Coorong (i.e. 1,288 GL) from this bundle of entitlements are quickly eroded under the climate change scenarios. This bundle of entitlements could not provide a long term solution under a changing climate and would put the Buy-Back investment at risk. Logically all water users could face a devaluation on their entitlements ability to provide water to offset this. However as Chart 2 illustrates that if the Buy-Back optimizes its enticements bundle this could be offset.

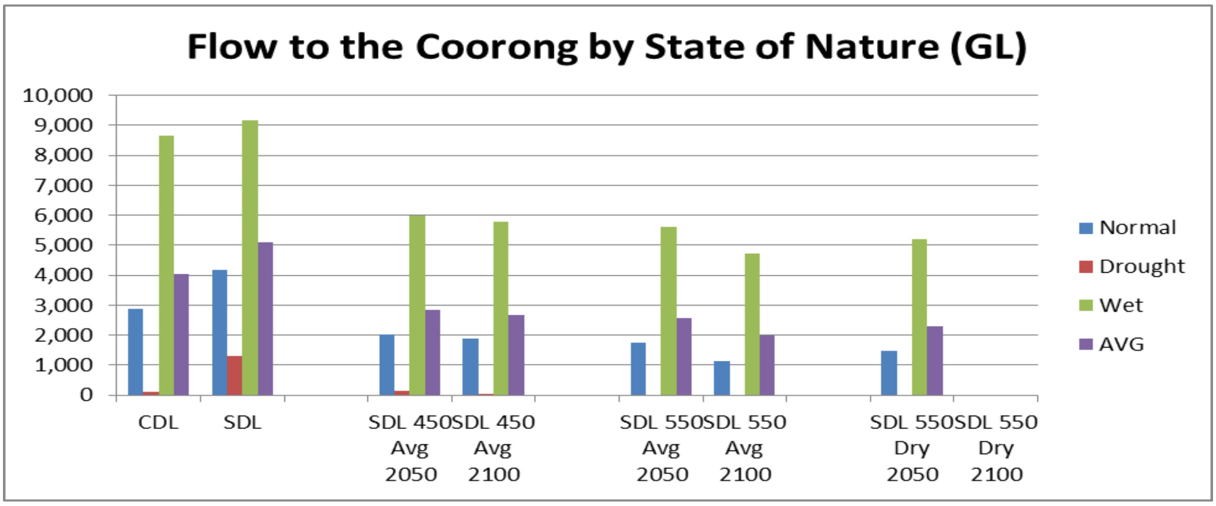

Chart 1: Climate Change impacts on Buy-Back decisions based on current climate

Chart 2 illustrates that the 1,000GL flow requirement to the Coorong can occur until 550 Dry 2050. The 550 Dry 2100 cannot be achieved as there are insufficient inflows to deliver 1,000 GL of water to the Coorong even without any surface irrigation diversions. However, the cost to achieve the 1,000 GL arriving at the Coorong in the drought state of nature under a 550 Dry Scenario by 2050, cannot be achieved within the $3.1 billion outlay under the Buy-Back, nor can it be achieved the proposed reductions in CDL by catchment proposed under the Basin Plan. However, as the increase to achieve the environmental targets in 550 Dry 2050 is $9.1 Billion. This figure exceeds the current outlay to purchase both entitlements ($3.1 Billion) and the modernization program ($5.8 billion). This then is an unrealistic outcome but highlights the issues needing considered in order to maximize the long term economic, social and environmental benefits of the Basin Plan under a changing climate. For the 550 Dry Scenario model constraints (where to purchase water and budget) were relaxed to find a solution.

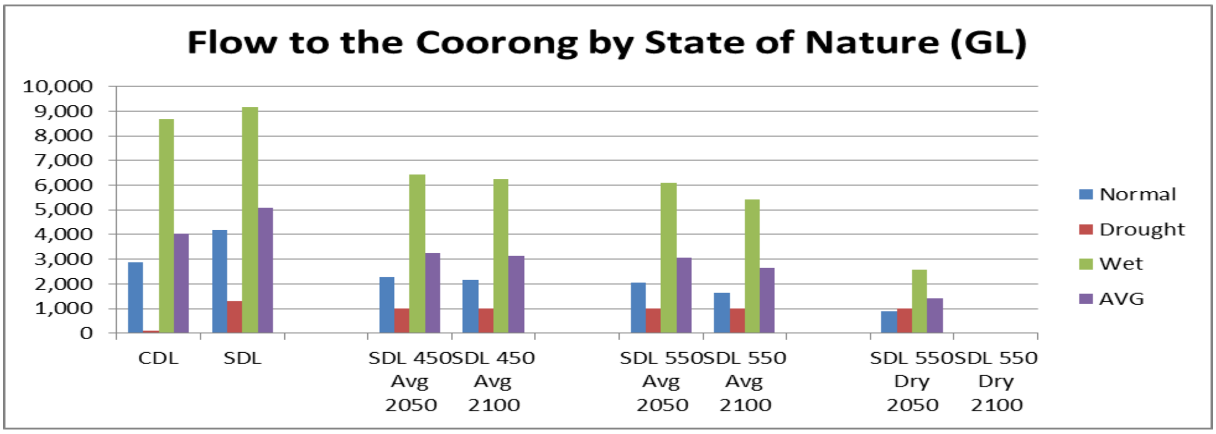

Chart 2: Incorporating climate change into the Buy-Back process

Under existing climate conditions that there will be more water arriving at the Coorong under the SDL, especially in drought conditions (i.e. increase from 93GL with CDL to nearly 1,300 GL with SDL), see Chart 2. The increased river flow under the proposed SDL then help reduce the salt arriving at Adelaide. However, as the climate changes these benefits are reduced especially when considering the average flows to the Coorong where the wet pulse flows are reduced when compared to the SDL. At the same time in order to still keep irrigation activities occurring to maximize net economic returns the production systems have switched to free water up in the drought states for the environmental flow. This then forces irrigators to use more water in the normal and wet states of nature degrading the quality of water arriving at Adelaide in both identified states and on average. This then suggests that long term planning for Adelaide's water supply will still be required.

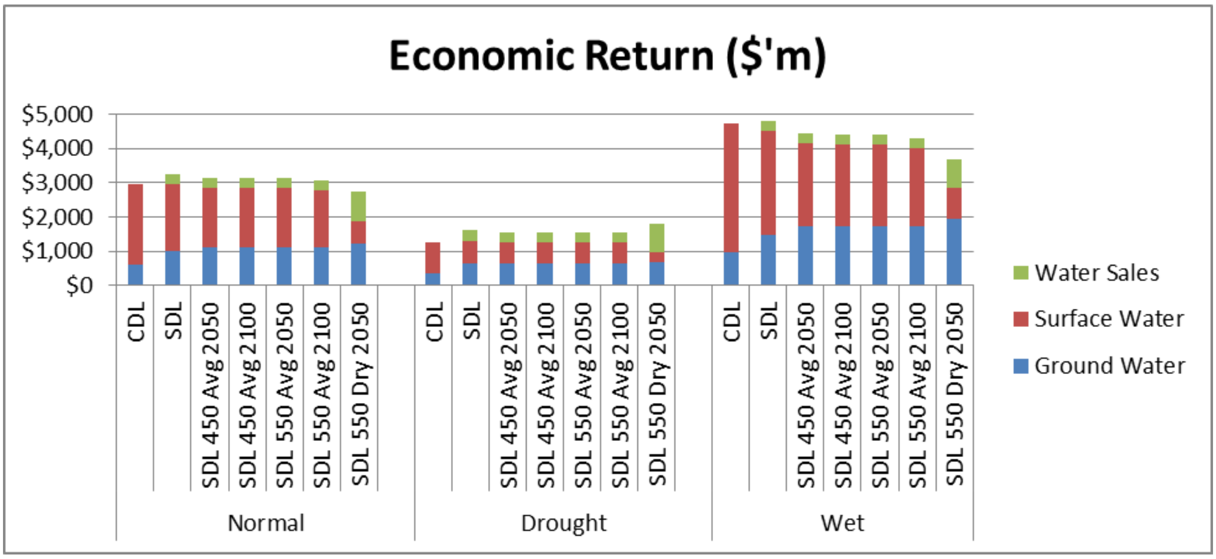

Chart 3: Economic Return by Water Source and by State of Nature

Initially the Basin Plan provides an average $100 million economic benefit (SDL) with a marked improvement in the drought state on nature. This increase is in part caused by the annuity from water sales but also from ground water usage, see Chart 3. Ground water has a secondary benefit to irrigators, the net economic return per ML increases under climate change as the remaining surface entitlements face value contracts. This suggests that the policy in fact causes social inequality based upon whether the irrigators own ground water entitlements over surface water entitlements.

In Chart 3 we see the contraction of perennials and dairy production systems, which require water in all states, is in part offset by an expansion in flexible and opportunistic cropping (i.e. only irrigate in the wet states of nature). The change in what is produced is also combined with a reduction in the area dedicated to irrigation activity. Area irrigated with surface water under the CDL is estimated at over 2.1 million Ha, falling to 1.8 million Ha under the SDL to only 0.4 million Ha in the SDL 550 Dry scenario.

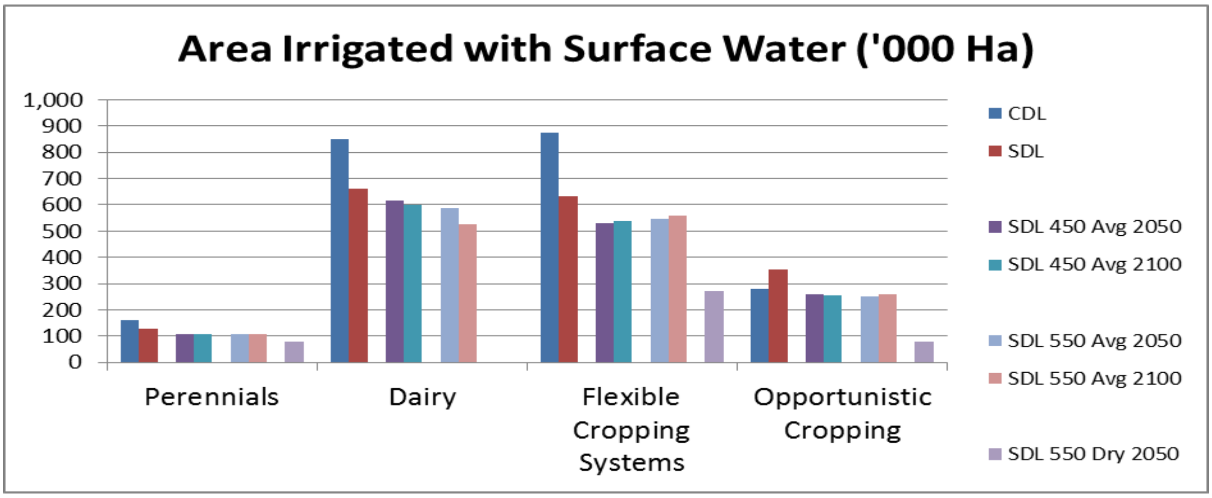

Chart3: Change in Production Systems (‘000 Ha)

5. CONCLUDING COMMENTS

The incorporation of environmental and social goals within economic frameworks is possible. Such strategies not only allow for the trade-offs to be determined within policy changes but illustrate the risks to policy objectives under climate variability and change impacts on water supply. The modeling suggests that by allowing reliable ground water resource use to increase, it offsets the reduction in surface water entitlements which have less supply reliability. This helps preserve the economic activity of irrigators under a changing climate. However, change in irrigation practices will occur and those with surface entitlements, including the environments share, will be worse off under a climate with decreased water supply. The Buy-Back process needs to consider the true objectives of the program in order to determine not only the spatial acquisition of the entitlements from willing sellers but the price it is willing to pay for specific water entitlement characteristics by state of nature. Such deliberations will also have to consider the future ability of surface entitlements to keep delivering the assumed true face value of the property right to deliver water.

Not only could the Buy-Back achieve the SDL on its own, improving social and environmental outcomes, but it also adequately compensates irrigators for their water. This suggests that the further expenditure under the irrigation modernization program can be questioned. Either it can be used to further offset existing and future negative externalities by returning more flows to the environment or questions about maximizing the benefits from this public expenditure needs to be raised. The failure to carefully stipulate the benefits and objectives of both publically funded programs then suggests a wealth transfer to irrigators. However, if the funds were designed to compensate the wider Basin community for the changes to existing systems then it can be justified.

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