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Comparing water options for irrigation farmers using Modern Portfolio Theory

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ABSTRACT

For irrigation farmers, the deregulation of water markets and consequent emergence of water as a tradeable commodity calls for a method of comparing traditional on-farm water options (growing crops) with off-farm market options (selling water seasonally, or selling water licences permanently). The option to diversify farm income in this way is a desirable future adaptation strategy in response to decreased and more variable water supplies. We demonstrate a method for comparing such options based on their risk-return characteristics. A framework commonly used in the finance sector is adapted to agricultural water decisions, and illustrated using a case-study farm from Australia's Riverina region. In our example, a range of potential farm management practices are examined for several future water availability scenarios, and then compared with a fixed-return option (selling water entitlements to the Australian Government's current water buy-back scheme). We demonstrate how the attractiveness of the scheme for farmers depends on future water availability levels. For any future allocation level, the best way to use water on-farm varies with the value of the fixed-return option. The farmer's decision on what portion of their water entitlement to sell provides them with the opportunity to tailor their operation's risk-return performance. This method is universally applicable wherever there is a mix of variable and fixed-return options, and offers a framework to assist farmers in conceptualizing comparisons between traditional on-farm uses for water and newer, market-based options.

1. Introduction

With deregulation of water markets, irrigation farmers are presented with new options for exploiting their water. Traditionally farmers gained financial returns from water via production of crops and livestock—today, some farmers can also use water itself as a tradeable commodity (Crase et al., 2000; McKay, 2005). Both water *entitlements* (licensed claim to a proportion of available district water resources) and *allocations* (seasonal water yields from those licences) can be traded in the Australian market. Forecast reductions and increased variability in water supplies (CSIRO, 2007; Hennessy et al., 2007) compel irrigation farmers to regard such new alternatives as potential future adaptation options in response to water scarcity (Bjornlund, 2003a, 2006; Howden et al., 2007). In addition to forecast climatic changes, Australia has implemented significant water policy reforms since the mid-1990s. These have additionally imposed uncertainties regarding future supply, passing the risk management burden from water authorities to irrigators. Bjornlund (2006) suggests this has created an increased need for risk management tools to assist irrigators in managing this increased uncertainty amidst an increasing range of exploitation options.

We present a method for assessing water exploitation options for irrigation farmers, wherever the joint possibility exists to use their water resources on-farm (irrigate crops or pastures), to sell them off-farm (either seasonally or permanently), or to employ some combination of both. We illustrate this method using a real case-study farm from the Riverina region of Australia—a major irrigation region straddling the Murray and Murrumbidgee Rivers in southern New South Wales and Northern Victoria (latitude 34°S to 35.5°S; longitude 144.5°E to 146.5°E). For this farm, available water can be used to irrigate various grain crops under a range of potential agronomic and irrigation strategies; it can also be sold seasonally on the open market to other users, or water entitlements could be traded permanently. Various combinations of these options are of course also possible. The farmer possesses a *general security* entitlement—these are characterized by greater risk in annual supply than *high security* entitlements, which are primarily owned by farmers with permanent plantings or infrastructure

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(crops such as grapes, citrus and stone fruits; dairy). The relative capital values of these entitlement types reflect this (Crean et al., 2001).

Aspects of the Australian water markets for both seasonal allocation and permanent entitlement have been widely studied and analyzed in the scientific literature (Bjornlund, 2003a,b, 2006; Bjornlund and Rossini, 2005, 2007, 2008; Brooks and Harris, 2008; Wheeler et al., 2008). Bjornlund (2006) explains that allocation markets have been used by irrigators to manage risk within and between seasons, whereas entitlement markets are associated with more long-term strategic positioning. The substantial risk in future supply has made irrigators more hesitant to use the entitlement market, and consequently the allocation markets are far more actively used for risk management. Prices therefore fluctuate much more widely than entitlement prices, especially during periods of exceptional drought (such as 2002–2003 and 2006–2007). The original rationale for introducing markets in permanent water entitlements was to facilitate a move of water from inefficient low-value production, to efficient high-value production (Bjornlund, 2003a). Although originally it was assumed this would occur via direct sale of entitlement, Bjornlund and Rossini (2005) suggest that seasonal water sales to higher value users are one of the more financially attractive adaptation options for lower-value irrigation farmers in times of low allocations. Producers of high value products with long-term investments in dairy herds and permanent plantings (grapes, citrus, and stone-fruits) have demonstrated they will pay high prices during periods of water scarcity to limit potential losses caused by insufficient irrigation (Bjornlund and Rossini, 2005; Brooks and Harris, 2008). This has been a life-line to growers of lower-valued irrigated cereal crops and grains over recent drought periods, with prices for seasonally traded water rising above A\$500 ML^{-1} to well beyond the A\$50–100 ML^{-1} which many of them can achieve from using the water to irrigate grain crops (Bjornlund, 2006), and substantially offsetting the impact for them of having less water available. The Australian experience therefore is that allocation markets have achieved many of the outcomes expected of the entitlement market (Bjornlund and Rossini, 2007).

Entitlement transfers do occur however (Crase et al., 2000; McKay, 2005; Bjornlund and Rossini, 2007) and prices paid in the market for water entitlements in parts of Australia increased by 15% p.a. over the 10-year period from 1993 to 2003 (Bjornlund and Rossini, 2007). This suggests that retaining ownership of entitlements while selling water seasonally made more sense for irrigated grain farmers over that period. Future growth in the value of entitlements however is less certain—Bjornlund and Rossini (2008) suggest it would be strange for entitlement prices keep rising if the seasonal allocations yielded by the entitlements are decreasing.

In Australia, the vast majority of entitlement trading has been rural-to-rural (Turral et al., 2005), unlike the US where trade prices have been significantly influenced by urban expansion and population growth (Person and Michelsen, 1994). More recently a new buyer has entered the Australian market in the form of the Australian Government with its "Water Buy-Back Scheme", aimed at recouping previously (over-) licensed irrigation water entitlement for environmental purposes (Australian Government, 2010a). Under this scheme, farmers may sell all or part of their entitlement for a tendered price per ML. They can then continue to conduct farming operations (either rain-fed or irrigated using water purchased on the open market), or alternately sell or lease the farm. This is particularly topical because the government is currently offering to buy back up to 100% of the farmer's licensed water (the full *entitlement*), while farmers have received only a fraction of their full entitlement in real water (*allocation*) each year over the past decade due to a combination of climatic and political factors (Gaydon et al., 2012). Other current initiatives of the Australian Government fund the purchase of efficient irrigation technology for farmers in return for the permanent relinquishment of an equivalent portion of the their licensed allocation (Australian Government, 2010b).

Clearly there are numerous off-farm options for a farmer to consider, each with their own inherent risks and potential returns. The likely future allocation variability, particularly for general security entitlement, is uncertain (CSIRO, 2007), and this complicates comparisons between on-farm and such off-farm water exploitation options. The analytical method we describe in this paper is suitable for comparing any on- and off-farm options providing risk-return estimates are available. For demonstration purposes we have chosen the Australian Government's Water Buyback Scheme as our example for an off-farm water option. This does not imply it is the best, or the most important option—it has purely been selected as an example. Here we compare this with a range of on-farm water investment options on the case-study farm (growing different types of crops for sale) using our proposed framework.

Assessing and comparing a range of options for water lends itself to methods routinely used in financial and share portfolio analysis, where investments are compared based on their risk-return characteristics. In the agricultural context, water options are rarely conceptualized in this way, largely due to difficulties in defining the risks associated with various on-farm cropping options. We propose that *Modern Portfolio Theory* presents a framework in which to make these comparisons.

1.1. Modern Portfolio Theory (MPT)

The Sharpe Ratio (S) can be used to express how well the return of an asset compensates the investor for the risk taken (Sharpe, 1994). It is defined by Eq. (1):

$$S = \frac{R - R_f}{\sigma} = \frac{\lfloor R - R_f \rfloor}{\sqrt{\mathrm{var}[R - R_f]}} \quad (1)$$

where R is the return from the investment in question, R_f is the 'risk-free' return, and σ is the standard deviation of the excess of the asset return over the 'risk-free' return. If R_f really is risk-free, then the variance in its returns is zero, hence the standard deviation of the excess is the same as the standard deviation in returns of the asset in question (Eq. (2); Scholz, 2007):

$$\sqrt{\mathrm{var}[R - R_f]} = \sqrt{\mathrm{var}[R]} \quad (2)$$

In the irrigated agricultural context, the 'risk free' return on a parcel of irrigation water may be considered as the price a farmer would receive for selling this water directly to another user at the start of the irrigation season, or permanently selling their irrigation water entitlement. The return (\$/Ml) from the water is then fixed. In the MPT sense 'risk' is defined as potential variability in returns—it has no connotations of missed opportunities or potential forgoing of gains from other options which have been forsaken, such as in common language usage. If a farmer decides instead to use the water on-farm to produce saleable products (crops), the risk of achieving a given return from the water increases because of intrinsic production and market risks such as climate variability, pest or disease problems and volatility in commodity price markets. Presumably the decision to use the water for irrigation would be based on the expectation that returns for on-farm water use would potentially be greater than from selling the water. The Sharpe Ratio may be used to assess the reward-to-risk characteristics of a range of possible options, providing that a reliable source for likely outcome distributions is available.

Irrigation farmers from Australia's Riverina can potentially invest their water in different ways on-farm in an attempt to