Agricultural Water Management 103 (2012) 33–42

Contents lists available at SciVerse ScienceDirect

Agricultural Water Management

journal homepage: www.elsevier.com/locate/agwat

The best farm-level irrigation strategy changes seasonally with fluctuating water availability

D.S. Gaydon[a,d,*], H. Meinke[b,d], D. Rodriguez[c]

[a] CSIRO Sustainable Ecosystems, Dutton Park Q 4102, Australia
[b] University of Tasmania, Tasmanian Institute of Agriculture, Hobart TAS 7001, Australia
[c] Agri-Science Queensland, Toowoomba Q 4350, Australia
[d] Centre for Crop Systems Analysis, Wageningen University, The Netherlands

ARTICLE INFO

Article history:
Received 20 July 2011
Accepted 19 October 2011
Available online 29 November 2011

Keywords:
Irrigation
Resource allocation
Whole farm modelling
Farming systems modelling

ABSTRACT

Around the globe farmers managing irrigated crops face a future with a decreased and more variable water supply. To investigate generic adaptation issues, a range of on-farm strategies were evaluated for apportioning limited water between fields and enterprises using a typical case-study farm from Australia's Riverina region. These strategies are compared for a range of seasonal water availability levels. The analysis did not address investment in new irrigation technologies or new crops, but focussed on irrigation intensity and crop choice amongst existing enterprises. Participatory engagement and whole-farm simulation modelling were our primary tools of research. The adaptation options found to best suit irrigation farming in years of high water availability were substantially different to those when water supplies were low. This illustrates strategic differences between irrigation farming in land-limited circumstances and water-limited circumstances. Our study indicates that the cropping and irrigation strategy leading to greatest farm returns changes on a season-by-season basis, depending primarily on the water availability level.

1. Introduction

Many arid irrigated agricultural regions of the world are expecting a future with decreased and more variable water supplies (Rijsberman, 2006; Christensen et al., 2007). Internationally, farmers are faced with similar questions on how to adapt: change crops, invest in more efficient irrigation technology and machinery, or alter agronomic and/or irrigation strategies? Accepting reduced production may be unavoidable but is rarely a desirable option, either from the farmer's perspective or global imperatives (the forecast requirement to increase global food production by 50% over the next 40 years (World Bank, 2008; von Grebmer et al., 2008)). Universally applicable methodologies are required to assess adaptation options for agriculture in the face of changed circumstances (Meinke et al., 2009; Howden et al., 2007). Australia's Riverina is a well-established irrigated region with access to traditionally secure water, now increasingly under pressure. It provides an ideal opportunity to explore adaptation options, generic principles, and research methodologies using a case-study approach, due to the ready availability of soil, crop, and farming system information, historical climate data, and farmers familiar with research involvement.

Irrigated agriculture in this region (latitude 34°S–35.5°S; longitude 144.5°E–146.5°E) involves a variety of crops such as rice, other cereals, pulses and oilseeds, as well as livestock. Farmers possess irrigation water *entitlements* (in ML) which licence them to a proportional share of available water resources in their district or irrigation area. An entitlement applies to either groundwater or surface-water resources (from rivers or diverted channel schemes) and represents the total volume of seasonal water procurable under each licence when the *allocation* is 100%. The *allocation*, expressed as a percentage (%), is a measure of total irrigation water available to the entire district system. It varies from season to season, and is determined and regulated by government. Available water determinations are made at the start of the water year (1 July–30 June) and allocation percentages are first announced in mid-August. They may then be upgraded on a monthly basis if inflows to large regional storage dams result in increased system water availability (New South Wales Department of Infrastructure, Planning, and Natural Resources, 2004). The seasonal volume of water that an individual irrigation farmer can access is calculated by multiplying their entitlement by the seasonal allocation percentage and dividing by 100. Australian water policy is complex and non-uniform between

* Corresponding author at: CSIRO Sustainable Ecosystems, Dutton Park Q 4102, Australia. Tel.: +61 738335705.
E-mail address: don.gaydon@csiro.au (D.S. Gaydon).

0378-3774/$ – see front matter. Crown Copyright © 2011 Published by Elsevier B.V. All rights reserved.
doi:10.1016/j.agwat.2011.10.015

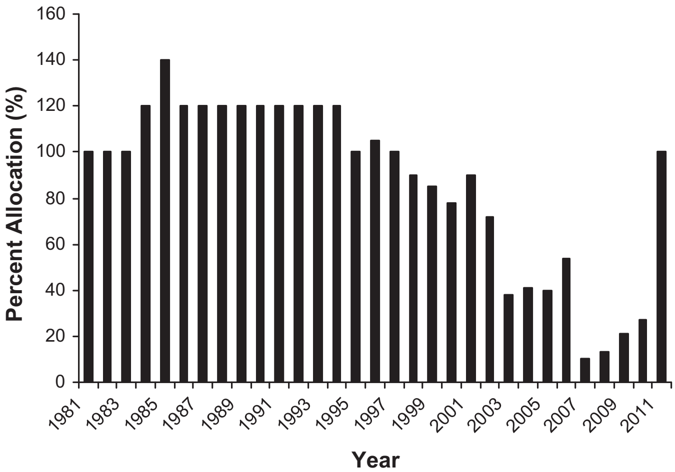

Fig. 1. Annual irrigation water allocations (percentage of licenced quota) for Murrumbidgee Irrigation Area, 1980/81–20010/11 seasons. The trend of 100% or greater allocation extends unbroken from 1998 back to 1912 (data not shown).

districts and regions (McKay, 2005; Crase et al., 2000), however Riverina irrigators are able to trade both seasonal allocation and entitlements (Bjornlund, 2003).

Recently, Riverina irrigators have experienced unprecedented restrictions in production due to low allocations brought about by a combination of climatic and political factors. Over the past decade, the volume of available water in the southern Basin has been around 40% less than the long-term average (MDBA, 2010). Average seasonal allocations over the last 15 years were below 50% of entitlement, with high variability. This is in contrast to a prior history of receiving at least 100% every season as far back as 1912 (depicted in Fig. 1, adapted from Gaydon et al., 2008; and Mcintyre et al., 2011).

Recent climate change projections suggest further decreases in regional water supply are likely. The Murray Darling Basin Sustainable Yields Project (CSIRO, 2007) suggested 9–14% reduction in water diversions for irrigation by 2030, whilst a 16–25% reduction in average Murray-Darling stream-flows by 2050 and 16–48% by 2100 has also been predicted (Pittock, 2003; Christensen et al., 2007; Hennessy et al., 2007). Such reductions in stream-flows are likely to have dramatic negative implications for future allocations in the Riverina (Jones and Pittock, 2003). Jones and Page (2002) suggest that a 15% drop in annual rainfall by 2030 could mean a 50% reduction in allocation levels. In Australia the supply of water for irrigation is not affected by climatic factors alone. Environmental policies and the National Competition Policy have also resulted in decreased water availability to irrigators (Adamson et al., 2007; Humphreys and Robinson, 2003; Murray-Darling Basin Authority, 2010). Clearly, the experience of the past is no longer an adequate reference for planning Australia's agricultural future (Jones, 2010), and innovative adaptation of on-farm water management practices are required to keep Riverina irrigators profitable in a future characterized by a reduced and more variable irrigation water supply.

There is a range of potential ways an individual irrigation farmer could adapt to decreased allocations. Essentially, the aim will be to increase efficiency (Keating et al., 2010) and increase water productivity, the production per unit of water applied, WP (Zwart and Bastiaanssen, 2004; Cai and Rosegrant, 2003; Seckler et al., 2003). Options such as partial-(deficit) irrigation may increase WP (Fereres and Soriano, 2007); changes in agronomic practices such as rotations, crop species and varieties (Howell, 2001), changes in residue (crop stubble) management practices (Tolk et al., 1999; Schillinger et al., 2010); and changes to proportional sharing of water between winter and summer crops (Lorite et al., 2007), all promise potential increases in WP. More transformational changes such as investing in new irrigation technology and crops (Harris, 2000; Wood and Finger, 2006; Maskey et al., 2006; Hafi et al., 2006) represent further options, as do disposing of water on the free market (Bjornlund, 2003; Crase et al., 2000). All these options are highly context-specific and decisions on suitable adaptations are strongly influenced by locally existing co-limitations (e.g. labour, capital, nutrients (Rodriguez et al., 2007), as well as socio-economic issues (Adger et al., 2009; Crane et al., 2008, 2010).

To ensure analysis of realistic adaptation options, participatory research with farmers is preferred (Robertson et al., 2000; Meinke et al., 2001; Carberry et al., 2002). Questions relating to use of limited water over numerous fields and enterprises on an individual farm necessarily requires a *whole-of-farm* modelling approach (Rodriguez et al., 2007). By working closely with farmers in developing detailed scenarios for testing, it is possible to incorporate a range of whole farm constraints (labour, machinery, irrigation cycles, etc.) without actually modelling them.

In this paper, we present a case-study approach using participatory research and the APSIM model (Keating et al., 2003) to compare a range of farmer-identified strategies for using limited irrigation water on a typical Riverina grain-cropping farm. The strategies encompass various irrigation intensities and different philosophies for apportioning water between existing on-farm enterprises, under a range of allocation scenarios. We did not consider new investment options (efficient irrigation technology) or new crops in this analysis. Nevertheless, we believe this case study approach demonstrates some generic principles and a method applicable to on-farm analysis in any region facing the contentious issues of how to use limited irrigation water resources on-farm across a range of allocations.

2. Materials and methods

2.1. Choice of case-study farm

The farm chosen for this analysis was an irrigated rice–cereal–soybean operation in the Murrumbidgee Irrigation Area (MIA), NSW. This dry region experiences a mean annual rainfall of 405 mm with an annual potential evaporation of 1780 mm. The 600 ha farm has 3265 ML of annual water entitlement (equivalent to approximately 544 mm ha^{-1}). The dominant soil type is a Gogeldrie Clay (Blackmore et al., 1956) with smaller areas of sandy-loam (Taylor and Hooper, 1938). The farm is typical of the region, and has been established to use a mixture of flood and furrow irrigation. Irrigation water is supplied via the channel network of Murrumbidgee Irrigation Ltd., and there is no on-farm water storage capacity.

2.2. Validating APSIM performance

The APSIM model was parameterized using relevant soil, crop and climate data, and subsequently tested against experimental data, average regional figures, and farmer historical records for both crop production and water-use variables. Satisfactory performance was achieved, with details provided in Appendix A.

2.3. Development of adaptation scenarios

Together with the case-study farmer, we envisaged a range of potential strategies for apportioning available water to different fields on his farm with varying levels of irrigation intensity. The options considered in this study consisted of changes in agronomic/irrigation practice and subsequent modifications to cropping areas and winter/summer crop proportions.